INHIBITORS OF IMPDH ENZYME

TECHNICAL FIELD OF THE INVENTION

The present invention relates to compounds which inhibit IMPDH. This invention also relates to pharmaceutical compositions comprising these compounds. The compounds and pharmaceutical compositions of this invention are particularly well suited for inhibiting IMPDH enzyme activity and consequently, may be advantageously used as therapeutic agents for IMPDH mediated processes. This invention also relates to methods for inhibiting the activity of IMPDH using the compounds of this invention and related compounds.

BACKGROUND OF THE INVENTION

The synthesis of nucleotides in organisms is required for the cells in those organisms to divide and replicate. Nucleotide synthesis in mammals may be achieved through one of two pathways: the *de novo* synthesis pathway or the salvage pathway. Different cell types use these pathways to a different extent.

Inosine-5'-monophosphate dehydrogenase (IMPDH; EC 1.1.1.205) is an enzyme involved in the *de novo* synthesis of guanosine nucleotides. IMPDH catalyzes the NAD-dependent oxidation of inosine-5'-monophosphate (IMP)

to xanthosine-5'-monophosphate (XMP) [Jackson R.C. et. al., Nature, 256, pp. 331-333, (1975)].

IMPDH is ubiquitous in eukaryotes, bacteria and protozoa [Y. Natsumeda & S.F. Carr, Ann. N.Y. Acad., 696, pp. 88-93 (1993)]. The prokaryotic forms share 30-40% sequence identity with the human enzyme. Regardless of species, the enzyme follows an ordered Bi-Bi reaction sequence of substrate and cofactor binding and product release. First, IMP binds to IMPDH. This is followed by the binding of the cofactor NAD. The reduced cofactor, NADH, is then released from the product, followed by the product, XMP [S.F. Carr et al., J. Biol. Chem., 268, pp. 27286-90 (1993); E.W. Holmes et al., Biochim. Biophys. Acta, 364, pp. 209-217 (1974)]. This mechanism differs from that of most other known NAD-dependent dehydrogenases, which have either a random order of substrate addition or require NAD to bind before the substrate.

Two isoforms of human IMPDH, designated type I and type II, have been identified and sequenced [F.R. Collart and E. Huberman, J. Biol. Chem., 263, pp. 15769-15772, (1988); Y. Natsumeda et. al., J. Biol. Chem., 265, pp. 5292-5295, (1990)]. Each is 514 amino acids, and they share 84% sequence identity. Both IMPDH type I and type II form active tetramers in solution, with subunit molecular weights of 56 kDa [Y. Yamada et. al., Biochemistry, 27, pp. 2737-2745 (1988)].

The *de novo* synthesis of guanosine nucleotides, and thus the activity of IMPDH, is particularly important in B and T-lymphocytes. These cells depend on the *de novo*, rather than salvage pathway to generate sufficient levels of nucleotides necessary to initiate a

proliferative response to mitogen or antigen [A.C. Allison et. al., Lancet II, 1179, (1975) and A.C. Allison et. al., Ciba Found. Symp., 48, 207, (1977)]. Thus, IMPDH is an attractive target for selectively inhibiting the immune system without also inhibiting the proliferation of other cells.

Immunosuppression has been achieved by inhibiting a variety of enzymes including for example, the phosphatase calcineurin (inhibited by cyclosporin and FK-506); dihydroorotate dehydrogenase, an enzyme involved in the biosynthesis of pyrimidines (inhibited by leflunomide and brequinar); the kinase FRAP (inhibited by rapamycin); and the heat shock protein hsp70 (inhibited by deoxyspergualin). [See B. D. Kahan, Immunological Reviews, 136, pp. 29-49 (1993); R. E. Morris, The Journal of Heart and Lung Transplantation, 12(6), pp. S275-S286 (1993)].

Inhibitors of IMPDH are also known. United States patents 5,380,879 and 5,444,072 and PCT publications WO 94/01105 and WO 94/12184 describe mycophenolic acid (MPA) and some of its derivatives as potent, uncompetitive, reversible inhibitors of human IMPDH type I (K_i=33 nM) and type II (K_i=9 nM). MPA has been demonstrated to block the response of B and T-cells to mitogen or antigen [A. C. Allison et. al., Ann. N. Y. Acad. Sci., 696, 63, (1993).

Immunosuppressants, such as MPA, are useful drugs in the treatment of transplant rejection and autoimmune diseases. [R. E. Morris, Kidney Intl., 49, Suppl. 53, S-26, (1996)]. However, MPA is characterized by undesirable pharmacological properties, such as gastrointestinal toxicity and poor bioavailability. [L.

M. Shaw, et. al., Therapeutic Drug Monitoring, 17, pp. 690-699, (1995)].

In addition, United States Patent No. 6,054,472 (which corresponds to PCT publication WO 97/40028) describes a novel class of compounds and pharmaceutical compositions which inhibit IMPDH. The described invention also relates to methods for inhibiting the activity of IMPDH using the compounds and pharmaceutical compositions and related compounds contained therein. Because the compounds described in this patent demonstrate a different metabolic profile than MPA and its derivatives, methods of this invention and the compounds used therein may offer advantages as therapeutics for IMPDH mediated disease. These advantages include increased overall therapeutic benefit and reduction in deleterious side effects.

Nucleoside analogs such as tiazofurin, ribavirin and mizoribine also inhibit IMPDH [L. Hedstrom, et. al. Biochemistry, 29, pp. 849-854 (1990)]. These compounds, which are competitive inhibitors of IMPDH, suffer from lack of specificity to this enzyme.

Mycophenolate mofetil, a prodrug which quickly liberates free MPA *in vivo*, was recently approved to prevent acute renal allograft rejection following kidney transplantation. [L. M. Shaw, et. al., Therapeutic Drug Monitoring, 17, pp. 690-699, (1995); H. W. Sollinger, Transplantation, 60, pp. 225-232 (1995)]. Several clinical observations, however, limit the therapeutic potential of this drug. [L. M. Shaw, et. al., Therapeutic Drug Monitoring, 17, pp. 690-699, (1995)]. MPA is rapidly metabolized to the inactive glucuronide *in vivo*. [A.C. Allison and E.M. Eugui, Immunological Reviews, 136,

pp. 5-28 (1993)]. The glucuronide then undergoes enterohepatic recycling causing accumulation of MPA in the gastrointestinal tract where it cannot exert its IMPDH inhibitory activity on the immune system. This effectively lowers the drug's *in vivo* potency, while increasing its undesirable gastrointestinal side effects.

More recently, IMPDH inhibitors of a different class have been described in PCT publication WO 97/40028.

It is also known that IMPDH plays a role in other metabolic events. Increased IMPDH activity has been observed in rapidly proliferating human leukemic cell lines and other tumor cell lines, indicating IMPDH as a target for anti-cancer as well as immunosuppressive chemotherapy [M. Nagai et. al., Cancer Res., 51, pp. 3886-3890, (1991)]. IMPDH has also been shown to play a role in the proliferation of smooth muscle cells, indicating that inhibitors of IMPDH, such as MPA or rapamycin, may be useful in preventing restenosis or other hyperproliferative vascular diseases [C. R. Gregory et al., Transplantation, 59, pp. 655-61 (1995); PCT publication WO 94/12184; and PCT publication WO 94/01105].

Additionally, IMPDH has been shown to play a role in viral replication in some viral cell lines. [S.F. Carr, J. Biol. Chem., 268, pp. 27286-27290 (1993)]. Analogous to lymphocyte and tumor cell lines, the implication is that the *de novo*, rather than the salvage, pathway is critical in the process of viral replication.

Thus, there remains a need for potent IMPDH inhibitors with improved pharmacological properties. Such inhibitors would have therapeutic potential as immunosuppressants, anti-cancer agents, anti-vascular

hyperproliferative agents, anti-inflammatory agents, antifungal agents, antipsoriatic and anti-viral agents.

SUMMARY OF THE INVENTION

The present invention provides compounds, and pharmaceutically acceptable derivatives thereof, that are useful as inhibitors of IMPDH. These compounds can be used alone or in combination with other therapeutic or prophylactic agents, such as anti-virals, anti-inflammatory agents, antibiotics, and immunosuppressants for the treatment or prophylaxis of transplant rejection and autoimmune disease.

Additionally, these compounds are useful, alone or in combination with other agents, as therapeutic and prophylactic agents for antiviral, anti-tumor, anti-cancer, anti-inflammatory agents, antifungal agents, antipsoriatic immunosuppressive chemotherapy and restenosis therapy regimens.

The invention also provides pharmaceutical compositions comprising the compounds of this invention, as well as multi-component compositions comprising additional IMPDH compounds together with an immunosuppressant. The invention also provides methods of using the compounds of this invention, as well as other related compounds, for the inhibition of IMPDH.

DETAILED DESCRIPTION OF THE INVENTION

In order that the invention herein described may be more fully understood, the following detailed description is set forth. In the description, the following abbreviations are used:

Designation	Reagent or Fragment
Ac	acetyl
Me	methyl

Et	ethyl
Bn	benzyl
CDI	carbonyldiimidazole
DIEA	diisopropylethylamine
DMAP	dimethylaminopyridine
DMF	dimethylformamide
DMSO	dimethylsulfoxide
EDC	1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride
EtOAc	ethyl acetate
THF	tetrahydrofuran

The following terms are employed herein:

Unless expressly stated to the contrary, the terms "$-SO_2-$" and "$-S(O)_2-$" as used herein refer to a sulfone or sulfone derivative (i.e., both appended groups linked to the S), and not a sulfinate ester.

The terms "halo" or "halogen" refer to a radical of fluorine, chlorine, bromine or iodine.

The term "immunosuppressant" refers to a compound or drug which possesses immune response inhibitory activity. Examples of such agents include cyclosporin A, FK506, rapamycin, leflunomide, deoxyspergualin, prednisone, azathioprine, mycophenolate mofetil, OKT3, ATAG, interferon and mizoribine.

The term "interferon" refers to all forms of interferons, including but not limited to alpha, beta and gamma forms.

IMPDH-mediated disease refers to any disease state in which the IMPDH enzyme plays a regulatory role in the metabolic pathway of that disease. Examples of IMPDH-mediated disease include transplant rejection and

autoimmune diseases, such as rheumatoid arthritis, multiple sclerosis, juvenile diabetes, asthma, and inflammatory bowel disease, as well as inflammatory diseases, cancer, viral replication diseases and vascular diseases.

For example, the compounds, compositions and methods of using them of this invention may be used in the treatment of transplant rejection (e.g., kidney, liver, heart, lung, pancreas (islet cells), bone marrow, cornea, small bowel and skin allografts and heart valve xenografts), rheumatoid arthritis, multiple sclerosis, juvenile diabetes, asthma, inflammatory bowel disease (Crohn's disease, ulcerative colitis), lupus, diabetes, mellitus myasthenia gravis, psoriasis, dermatitis, eczema, seborrhea, pulmonary inflammation, eye uveitis, hepatitis, Grave's disease, Hashimoto's thyroiditis, Behcet's or Sjorgen's syndrome (dry eyes/mouth), pernicious or immunohaemolytic anaemia, idiopathic adrenal insufficiency, polyglandular autoimmune syndrome, and glomerulonephritis, scleroderma, lichen planus, viteligo (depigmentation of the skin), autoimmune thyroiditis, and alveolitis, inflammatory diseases such as osteoarthritis, acute pancreatitis, chronic pancreatitis, asthma and adult respiratory distress syndrome, as well as in the treatment of cancer and tumors, such as solid tumors, lymphomas and leukemia, vascular diseases, such as restenosis, stenosis and atherosclerosis, and DNA and RNA viral replication diseases, such as retroviral diseases, and herpes.

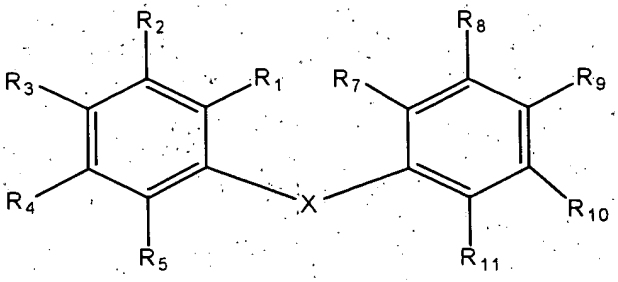
Additionally, IMPDH enzymes are also known to be present in bacteria and thus may regulate bacterial growth. As such, the IMPDH-inhibitor compounds,

compositions and methods described herein may be useful in treatment or prevention of bacterial infection, alone or in combination with other antibiotic agents.

The term "treating" as used herein refers to the alleviation of symptoms of a particular disorder in a patient or the improvement of an ascertainable measurement associated with a particular disorder. As used herein, the term "patient" refers to a mammal, including a human.

The terms "HBV", "HCV" and "HGV" refer to hepatitis-B virus, hepatitis-C virus and hepatitis-G virus, respectively.

According to one embodiment, the invention provides compounds of formula I:



wherein:

X is selected from $-C(O)-N(R_6)-$, $-N(R_6)-C(O)-$, $-CH_2-N(R_6)-$, $-N(R_6)-CH_2-$, $-N(R_6)-S(O)_2-$, $-S(O)_2-N(R_6)-$, $-C(R_{12})(R_{12})-C(O)-$, $-C(O)-C(R_{12})(R_{12})-$, $-C(R_{12})(R_{12})-S(O)_2-$, $-S(O)_2-C(R_{12})(R_{12})-$, $-S(O)_2-O-$, $-O-S(O)_2-$, $-NR_6-C(O)-Y-$ or $Y-C(O)-NR_6-$; wherein

each R_6 is independently selected from hydrogen, C_1-C_4 straight or branched alkyl, C_2-C_4 straight or branched alkenyl or alkynyl, Ar-substituted-C_1-C_4 straight or branched alkyl, or Ar-substituted-C_2-C_4 straight or branched alkenyl or alkynyl; wherein

R_6 is optionally substituted with up to 3 substituents independently selected from halo, hydroxy, nitro, cyano or amino;

each R_{12} is independently selected from R_6, W-[C_1-C_4 straight or branched alkyl], W-[C_2-C_4 straight or branched alkenyl or alkynyl], Ar-substituted-[W-[C_1-C_4 straight or branched alkyl]], Ar-substituted-[W-[C_2-C_4 straight or branched alkenyl or alkynyl]], O-Ar, $N(R_6)$-Ar, S-Ar, S(O)-Ar, $S(O)_2$-Ar, S-C(O)H, $N(R_6)$-C(O)H, or O-C(O)H; wherein

W is O-, O-C(O)-, S-, S(O)-, $S(O)_2$-, S-C(O)-, $N(R_6)$-, or $N(R_6)$-C(O)-; and wherein

each R_{12} is optionally and independently substituted with up to 3 substituents independently selected from halo, hydroxy, nitro, cyano or amino.

and

Y is selected from -O-, -S-, -C≡C-, $-C(R_{12})_2-C(R_{12})_2-$, $-C(R_{12})_2-$ or $-C(R_{12})=C(R_{12})-$; wherein

each of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} and R_{11} is independently selected from hydrogen, halo, hydroxy, cyano, nitro, amino, $-C(O)NH_2$, Z-[(C_1-C_4)-straight or branched alkyl], Z-[(C_2-C_4)-straight or branched alkenyl or alkynyl], Ar-substituted-[(C_1-C_4)-straight or branched alkyl], Ar-substituted-[(C_2-C_4)-straight or branched alkenyl or alkynyl], Ar, Q-Ar, [(C_1-C_4)-straight or branched alkyl]-Q-Ar, [(C_2-C_4)-straight or branched alkenyl or alkynyl]-Q-Ar, O-[(C_1-C_4)-straight or branched alkyl]-Q-Ar, O-[(C_2-C_4)-straight or branched alkenyl or alkynyl]-Q-Ar, or any two adjacent R groups may be taken together with the carbon atoms to which they are bound to form a 5 to 6-membered aromatic carbocyclic or heterocyclic ring; wherein

Z is selected from a bond, O-, S-, $S(O)_2$-, C(O)-, OC(O)-, or N(H)C(O)-;

Q is selected from O, -O-C(O)-, -C(O)-O-, -N(H)-C(O)-O-, -O-N(H)-C(O)-, -N(H)-C(O)-, -C(O)-N(H)-, -O-C(O)-N(H)-, or -C(O)-N(H)-O-;

Ar is selected from phenyl, 1-naphthyl, 2-naphthyl, indenyl, azulenyl, fluorenyl, anthracenyl, 2-furyl, 3-furyl, 2-thienyl, 3-thienyl, 2-pyridyl, 3-pyridyl, 4-pyridyl, pyrrolyl, oxazolyl, thiazolyl, imidazolyl, pyraxolyl, 2-pyrazolinyl, pyrazolidinyl, isoxazolyl, isotriazolyl, 1,2,3-oxadiazolyl, 1,2,3-triazolyl, 1,3,4-thiadiazolyl, pyridazinyl, pyrimidinyl, pyrazinyl, 1,3,5-triazinyl, 1,3,5-trithianyl, indolizinyl, indolyl, isoindolyl, 3H-indolyl, indolinyl, benzo[b]furanyl, benzo[b]thiophenyl, 1H-indazolyl, benzimidazolyl, benzthiazolyl, purinyl, 4H-quinolizinyl, quinolinyl, isoquinolinyl, 1,2,3,4-tetrahydro-isoquinolinyl, cinnolinyl, phthalazinyl, quinazolinyl, quinoxalinyl, 1,8-naphthyridinyl, peridinyl, carbazolyl, acridinyl, phenazinyl, phenothiazinyl or phenoxazinyl or other chemically feasible monocyclic, bicyclic or tricyclic ring systems, wherein each ring consists of 5 to 7 ring atoms and wherein each ring comprises 0 to 3 heteroatoms independently selected from N, O and S;

R_{13} is selected from [C_1-C_{12} straight or branched alkyl] or, [C_2-C_{12} straight or branched alkenyl or alkynyl]; wherein R_{13} is optionally substituted with 1 to 4 substituents independently selected from R_{14} or R_{15}, wherein

each R_{14} is a monocyclic or a bicyclic ring system consisting of 3 to 7 members per ring, wherein said ring system optionally comprises up to 4 heteroatoms selected from N, O, and S; wherein a CH_2 adjacent to said N, O or S

may be substituted with C(O); and wherein R_{14} optionally comprises up to 2 substituents independently selected from (C_1-C_4)-straight or branched alkyl, (C_2-C_4)-straight or branched alkenyl, 1,2-methylenedioxy, 1,2-ethylenedioxy, $(CH_2)_n-R_{16}$, $-S-(CH_2)_n-R_{16}$, $-S(O)-(CH_2)_n-R_{16}$, $-S(O)_2-(CH_2)_n-R_{16}$, $-O-(CH_2)_n-R_{16}$, or $-N(R_{18})-(CH_2)_n-R_{16}$

wherein n is 0, 1 or 2;

R_{16} is selected from halogen, -CN, $-NO_2$, $-CF_3$, $-OCF_3$, -OH, $-S-(C_1-C_4)$-alkyl, $-S(O)-(C_1-C_4)$-alkyl, $-S(O)_2-(C_1-C_4)$-alkyl, $-NH_2$, $-NH-(C_1-C_4)$-alkyl, $-N((C_1-C_4)\text{-alkyl})_2$, COOH, $C(O)-O-(C_1-C_4)$-alkyl or $O-(C_1-C_4)$-alkyl; and

each R_{15} is independently selected from $-OR_{17}$, or $-N(R_{18})_2$;

R_{17} is selected from hydrogen, $-(C_1-C_6)$-straight alkyl, $-(C_1-C_6)$-straight alkyl-Ar, $-C(O)-(C_1-C_6)$-straight or branched alkyl, -C(O)-Ar, or $-(C_1-C_6)$-straight alkyl-CN; and

each R_{18} is independently selected from $-(C_1-C_6)$-straight or branched alkyl, $-(C_1-C_6)$-straight or branched alkyl-Ar, $-(C_1-C_6)$-straight alkyl-CN, $-(C_1-C_6)$-straight alkyl-OH, $-(C_1-C_6)$-straight alkyl-OR_{17}, $-C(O)-(C_1-C_6)$-straight or branched alkyl, -C(O)-Ar, $-S(O)_2-(C_1-C_6)$-straight or branched alkyl, or $-S(O)_2$-Ar; wherein

any alkyl, alkenyl or alkynyl group is optionally substituted with 1 to 3 independently selected halo groups; and

any Ar, aromatic carbocyclic ring or heterocyclic ring is optionally substituted with 1 to 3 substituents independently selected from halo, hydroxy, nitro, cyano, amino, (C_1-C_4)-straight or branched alkyl; $O-(C_1-C_4)$-straight or branched alkyl, (C_2-C_4)-straight or branched alkenyl or alkynyl, or $O-(C_2-C_4)$-straight or branched alkenyl or alkynyl; and

any Ar, aromatic carbocyclic ring or heterocyclic ring is optionally benzofused.

In addition, in these compounds, at least two of R_1, R_2, R_3, R_4, or R_5 is hydrogen;

no more than two of R_1, R_2, R_3, R_4, or R_5 comprises Ar;

at least two of R_7, R_8, R_9, R_{10} or R_{11} is hydrogen; and

no more than two of R_7, R_8, R_9, R_{10} or R_{11} comprises Ar.

The compounds of this invention specifically exclude those wherein X is $-NH-S(O)_2-$ or $-S(O)_2-N(H)-$, one of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} is O-(C_1-C_4)-straight or branched alkyl, seven of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} is hydrogen and the remaining two of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} are bound together to form a 5 to 6-membered aromatic carbocyclic or heterocyclic ring.

Also excluded are compounds wherein X is $-NH-S(O)_2-$ or $-S(O)_2-N(H)-$, two of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} are O-(C_1-C_4)-straight or branched alkyl, seven of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} is hydrogen and the remaining one of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} is $-NO_2$, -CN or -Ar.

Another set of compounds excluded from the present invention are those wherein X is $-NH-S(O)_2-$ or $-S(O)_2-N(H)-$, two of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} are O-(C_1-C_4)-straight or branched alkyl, six of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} is hydrogen and the remaining two of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} are both halo.

Yet another set of compounds excluded are those wherein X is $-NH-S(O)_2-$ or $-S(O)_2-N(H)-$, one of R_1, R_2, R_3,

R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} is Ar and the remaining 9 of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} are each hydrogen.

Another set of excluded compounds are those wherein X is -N(H)-C(O)-S- or -S-C(O)-N(H)-, one of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} is -OH, eight of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} are hydrogen and the remaining one of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} is halo; and those wherein X is -N(H)-C(O)-S- or -S-C(O)-N(H)-, one of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} is -OH, seven of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} are hydrogen, one of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} is O-(C_1-C_4)-straight or branched alkyl and the remaining one of R_1, R_2, R_3, R_4, R_5, R_7, R_8, R_9, R_{10} or R_{11} is halo or (C_1-C_4)-straight or branched alkyl.

Finally, another set of excluded compounds are those wherein, when X is -C(O)-N(R_6)- or -N(R_6)-C(O)-, two adjacent groups selected from either R_1, R_2, R_3, R_4 and R_5, or from R_7, R_8, R_9, R_{10} and R_{11} may not be taken together with the carbon atoms to which they are bound to form a 6-membered aromatic carbocyclic ring.

The above-described exclusions from the compounds of this invention reflect compounds which are commercially available. However, those compounds are not known or suggested to inhibit IMPDH, nor have they ever been know or suggested to be formulated with a pharmaceutically acceptable adjuvant, carrier or excipient. Accordingly, these compounds are not excluded from aspects of this invention which involve any methods or compositions recited below.

The term "heterocyclic ring" as used herein refers to a ring which comprises 1 to 4 heteroatoms independently selected from N, O or S.

The terms "Ar-substituted-(C_1-C_4)-straight or branched alkyl" and "Ar-substituted-(C_2-C_4)-straight or branched alkenyl or alkynyl" denote that one or more Ar groups may be attached to the alkyl, alkenyl or alkynyl chain at any chemically feasible position on the chain, including the termini.

References to "[branched alkyl, alkenyl or alkynyl]-Ar" or "[branched alkyl, alkenyl or alkynyl]-Q-Ar" denote that an "Ar" or "Q-Ar" moiety is attached to one or more terminal ends of the branched alkyl, alkenyl or alkynyl chain.

According to a preferred embodiment X is selected from $-C(O)-N(R_6)-$, $-N(R_6)-C(O)-$, $-CH_2-N(R_6)-$, or $-N(R_6)-CH_2-$ or $-N(R_6)-C(O)-Y$. More preferably, X is $-N(R_6)-C(O)-Y$. Most preferably X is $-N(R_6)-C(O)-C(R_{12})=C(R_{12})-$.

According to another preferred embodiment, R_1 is selected from H, (C_1-C_4)-straight or branched alkyl, OH, $O-(C_1-C_4)$-straight or branched alkyl, O-Ar, OCF_3, halo, cyano or $S-(C_1-C_4)$-straight or branched alkyl. In an alternate preferred embodiment, R_1 is H when R_2 is not H.

R_2 is preferably selected from H, (C_1-C_4)-straight or branched alkyl, Ar, $O-(C_1-C_4)$-straight or branched alkyl, O-Ar, OCF_3, halo, cyano, $C(O)NH_2$ or $S(O)_2-(C_1-C_4)$-straight or branched alkyl. More preferably, R_2 is H.

R_3 is preferably selected from H, Ar, cyano, $O-(C_1-C_4)$-straight or branched alkyl, O-Ar, $S-(C_1-C_4)$-straight or branched alkyl, CF_3 or OCF_3.

In another preferred embodiment, R_4 is selected from H, (C_1-C_4)-straight or branched alkyl, OH, $O-(C_1-C_4)-$

straight or branched alkyl, O-Ar, OCF_3, halo, cyano or S-(C_1-C_4)-straight or branched alkyl.

R_5 is preferably selected from H, (C_1-C_4)-straight or branched alkyl, Ar, O-(C_1-C_4)-straight or branched alkyl, O-Ar, OCF_3, halo, cyano, $C(O)NH_2$ or $S(O)_2$-(C_1-C_4)-straight or branched alkyl. More preferably, R_5 is H.

According to another preferred embodiment, R_7 is selected from H, OH, $OC(O)$-(C_1-C_4)-straight or branched alkyl, O-(C_1-C_4)-straight or branched alkyl, O-Ar, amino, or $N(H)C(O)$-(C_1-C_4)-straight or branched alkyl. Even more preferred is when R_7 is OH.

R_8 is preferably H, (C_1-C_4)-straight or branched alkyl, O-(C_1-C_4)-straight or branched alkyl, or (C_1-C_4)-straight or branched alkyl-$N(H)C(O)O$-Ar.

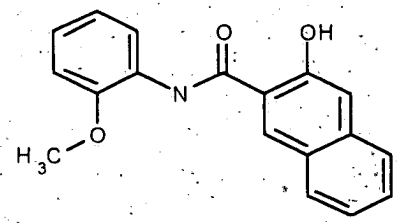
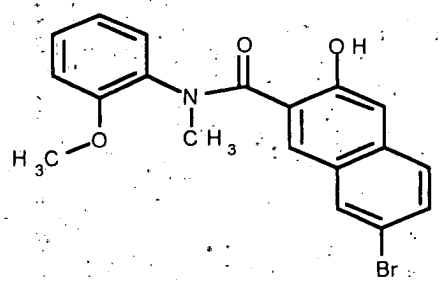
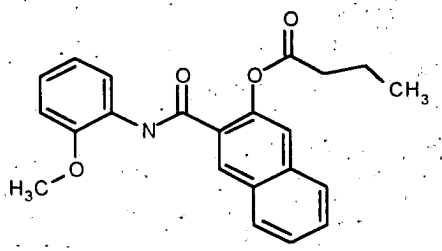
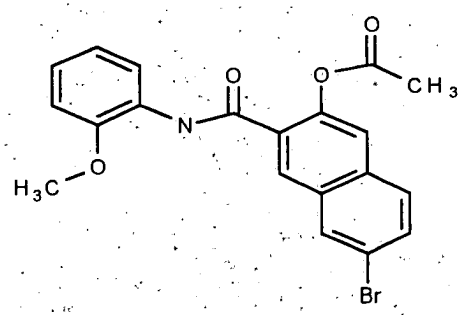
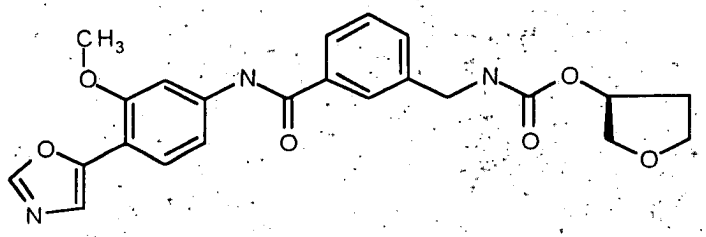
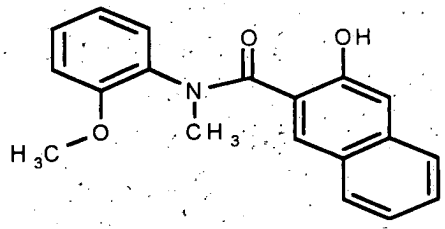
According to another preferred embodiment, R_9 is selected from H, (C_1-C_4)-straight or branched alkyl, O-(C_1-C_4)-straight or branched alkyl, or R_9 is taken together with R_{10} and the carbon atoms to which they are bound to form a fused benzene ring. More preferred is when R_9 and R_{10} are taken together with the carbon atoms to which they are bound to form a fused benzene ring.

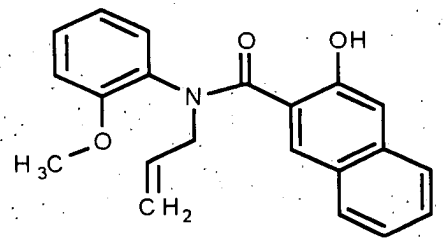
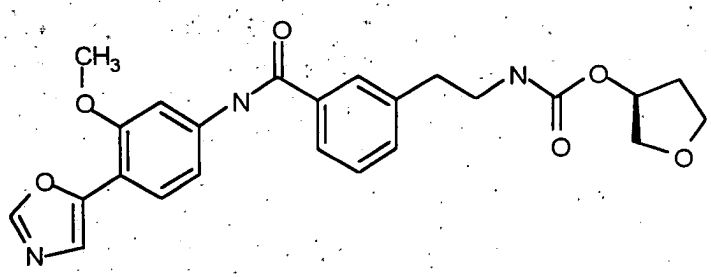
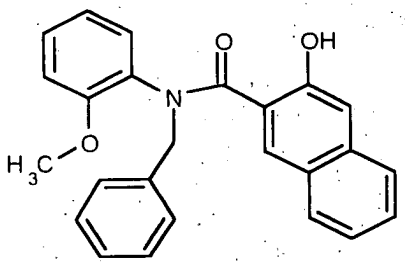
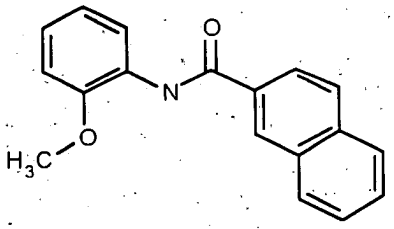
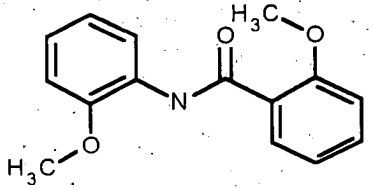
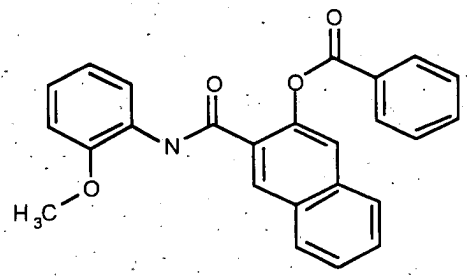
According to a further preferred embodiment, R_{10} is selected from H, (C_1-C_4)-straight or branched alkyl, O-(C_1-C_4)-straight or branched alkyl, or R_{10} is taken together with R_9 and the carbon atoms to which they are bound to form a fused benzene ring.

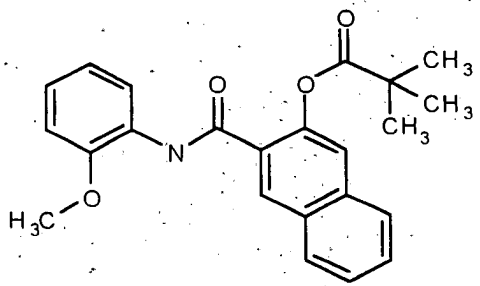
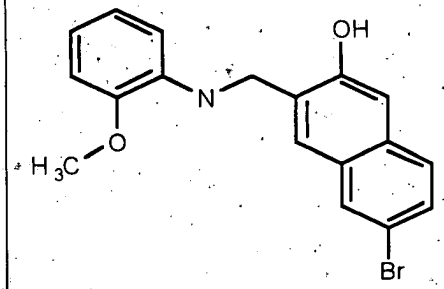
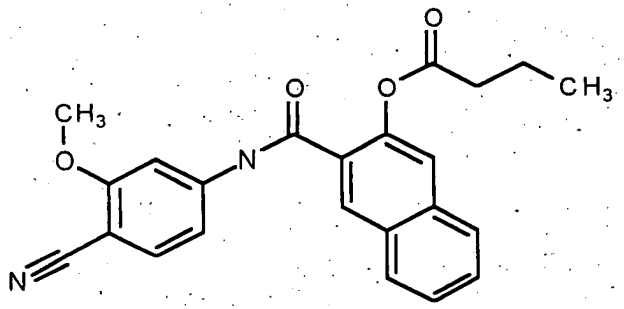
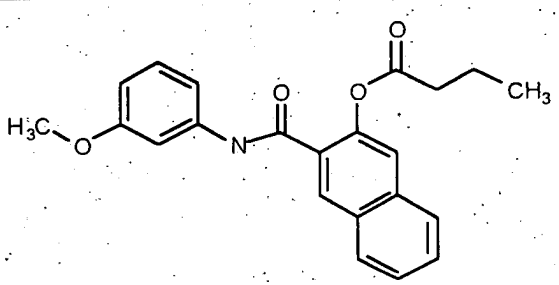
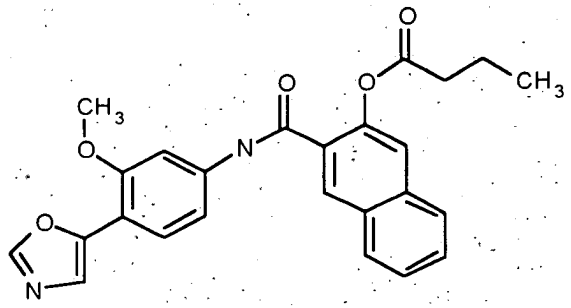
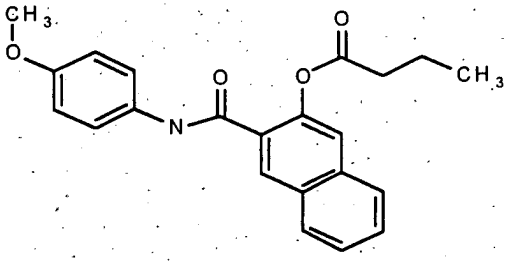
In another preferred embodiment, R_{11} is selected from H, OH, $OC(O)$-(C_1-C_4)-straight or branched alkyl, O-(C_1-C_4)-straight or branched alkyl, O-Ar, amino, or $N(H)C(O)$-(C_1-C_4)-straight or branched alkyl. More preferably, R_{11} is H.

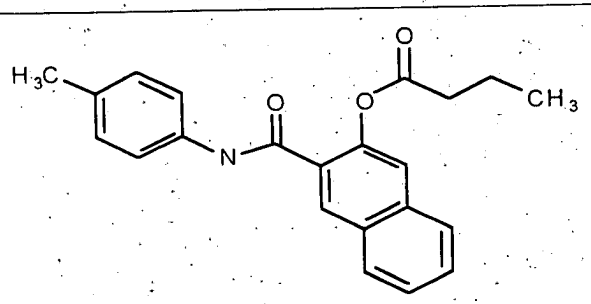
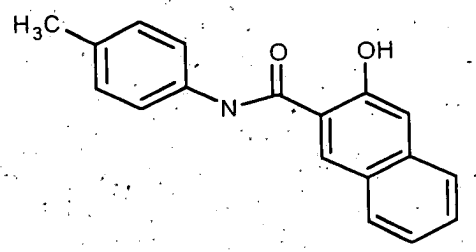
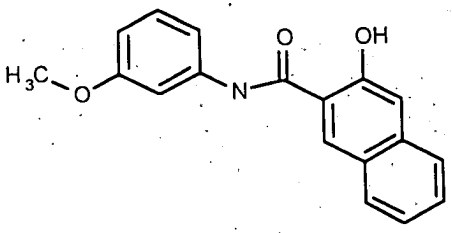
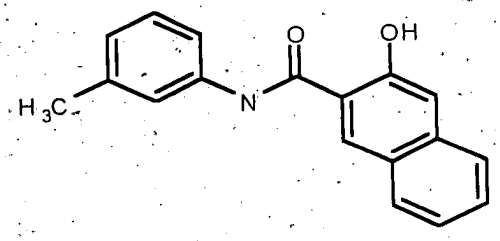
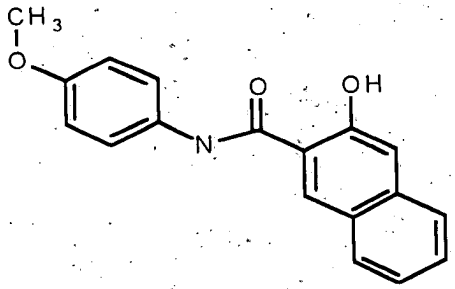
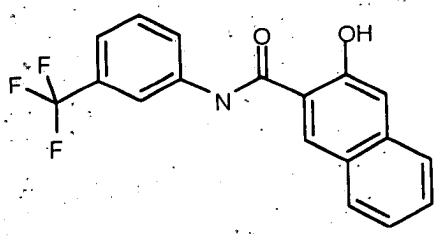
According to another embodiment, preferred compounds of the invention are listed in the table below.

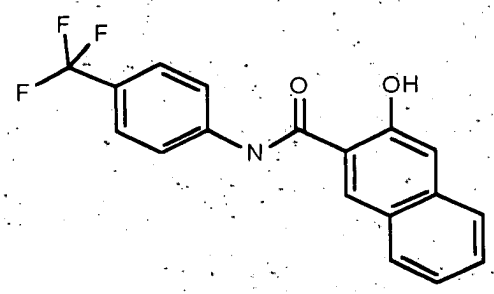
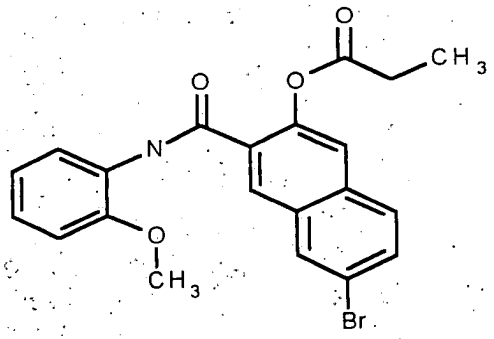
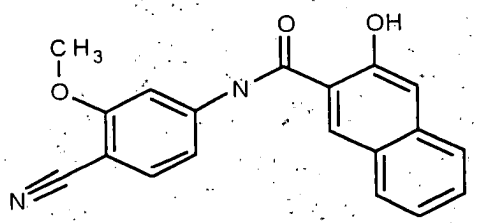
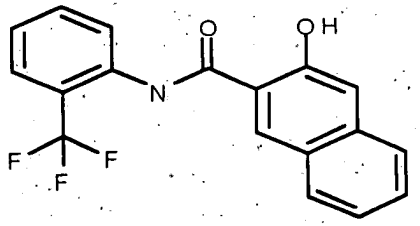
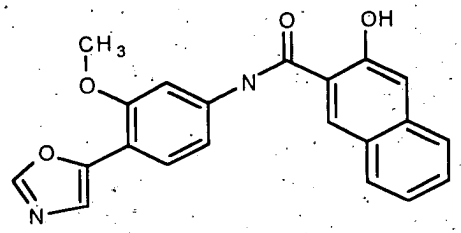
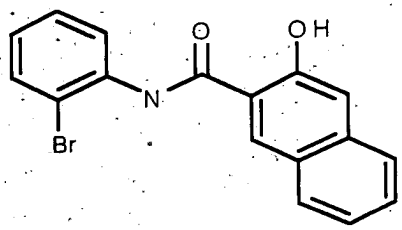
Table 1. Preferred compounds.

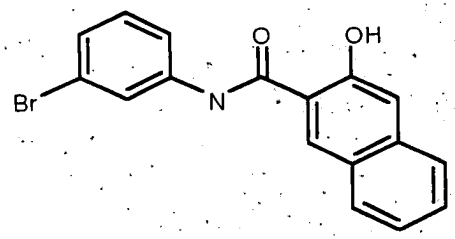
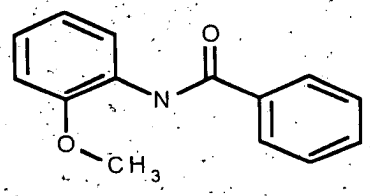
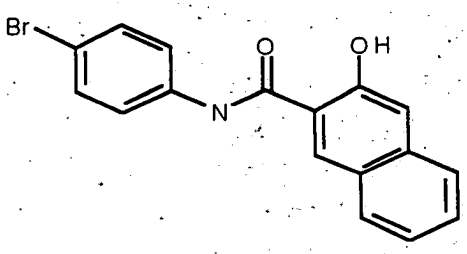
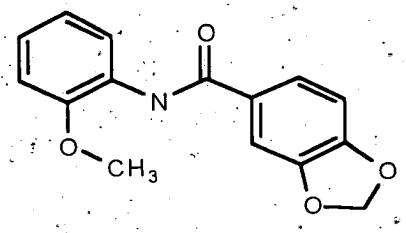
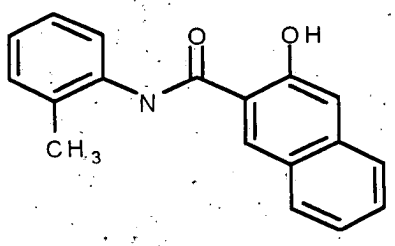
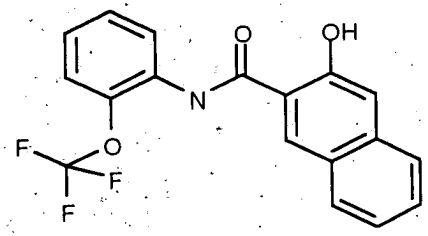
Cmpd	Molecular Structure	Cmpd	Molecular Structure
100		103	
101		104	
102		105	

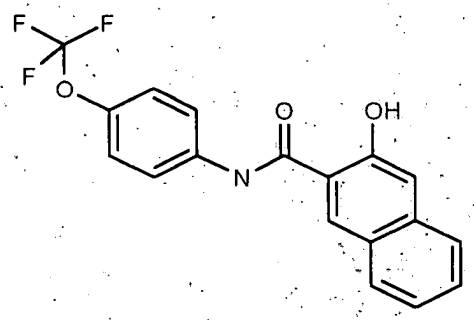
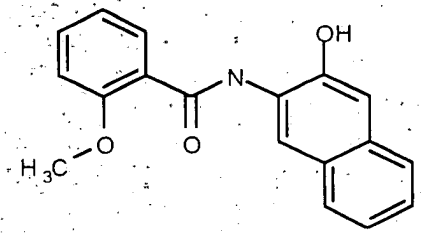
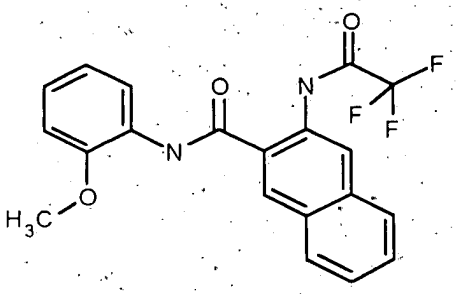
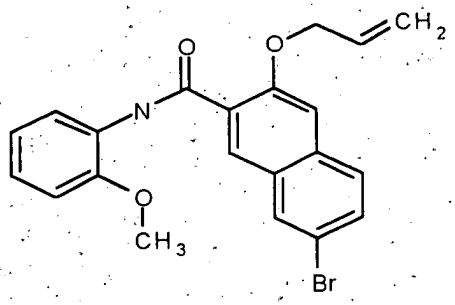
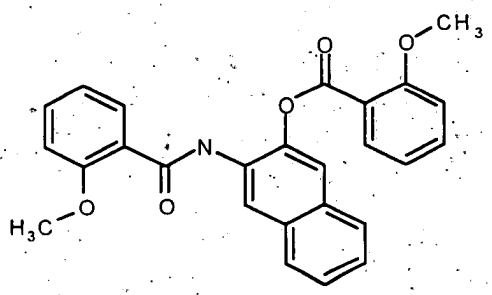
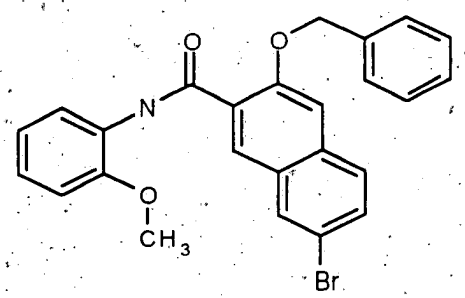
Cmpd	Molecular Structure	Cmpd	Molecular Structure
106		109	
107		110	
108		111	

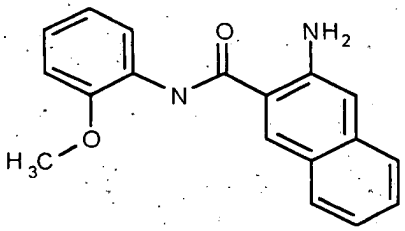
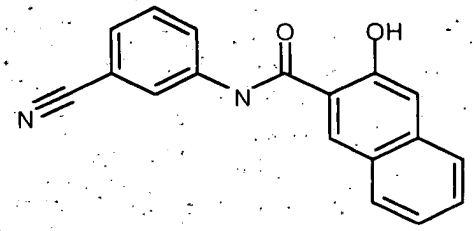
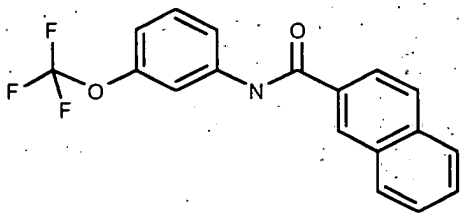
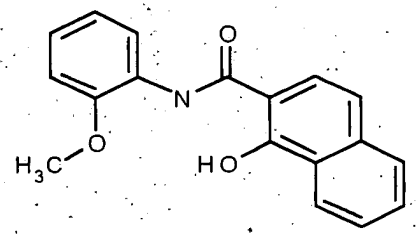
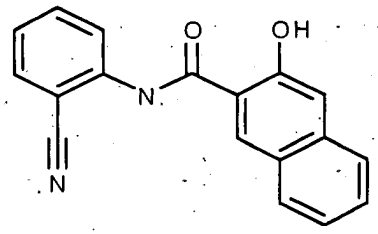
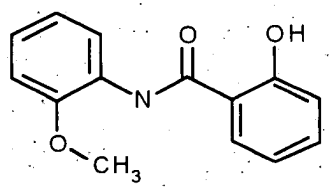
Cmpd	Molecular Structure	Cmpd	Molecular Structure
112		115	
113		116	
114		117	

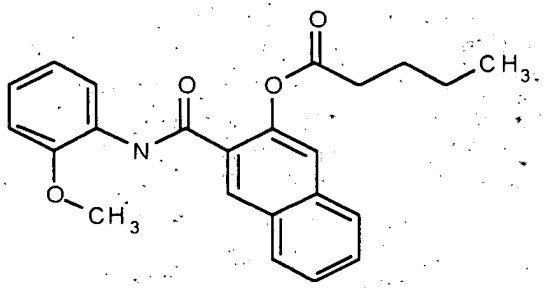
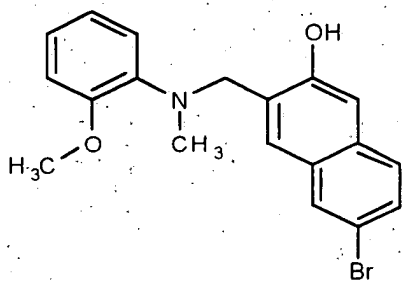
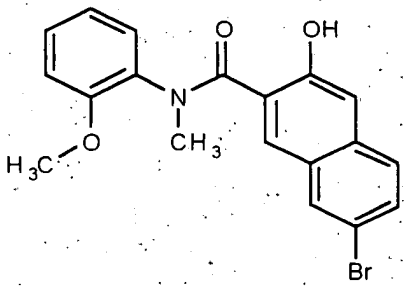
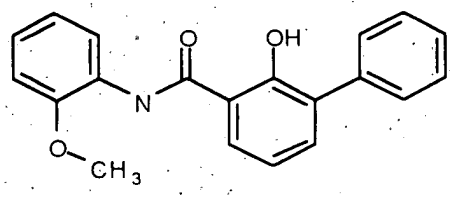
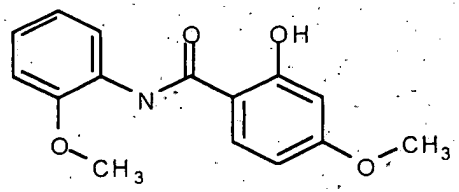
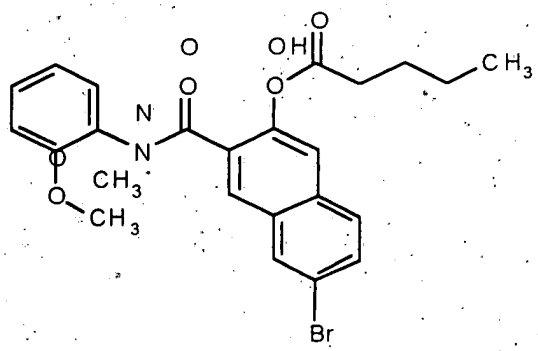
Cmpd	Molecular Structure	Cmpd	Molecular Structure
118		121	
119		122	
120		123	

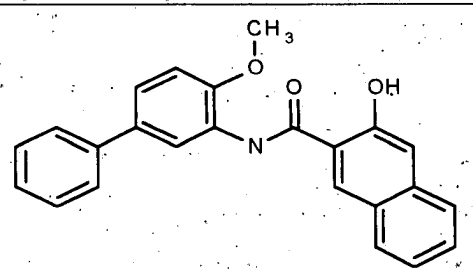
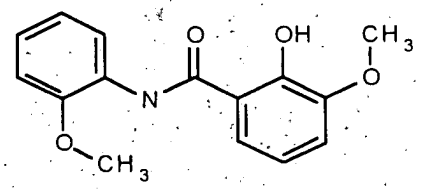
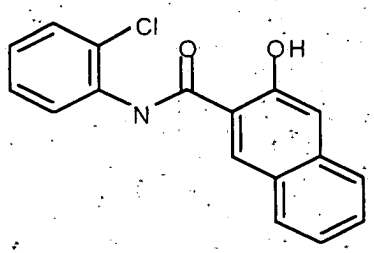
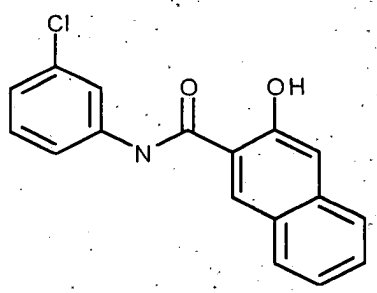
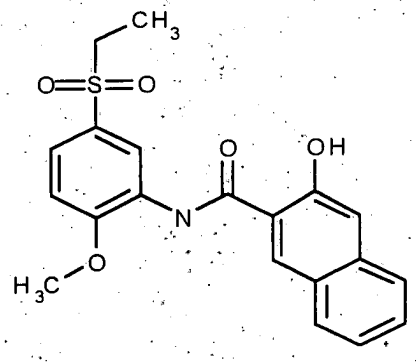
Cmpd	Molecular Structure	Cmpd	Molecular Structure
124		127	
125		128	
126		129	

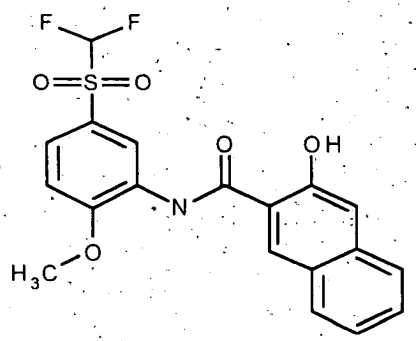
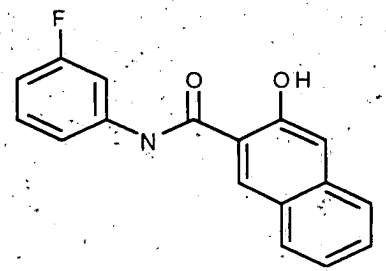
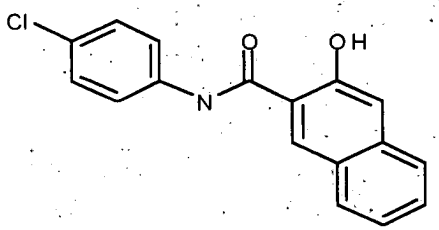
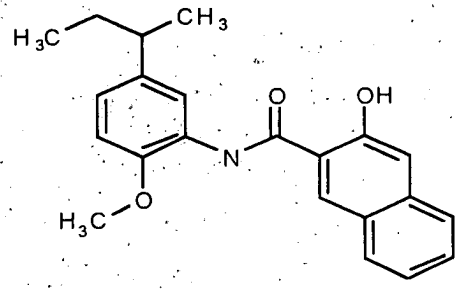
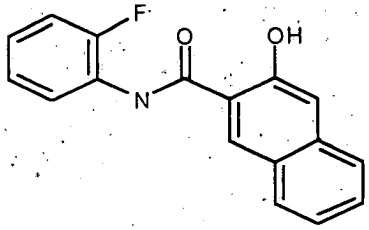
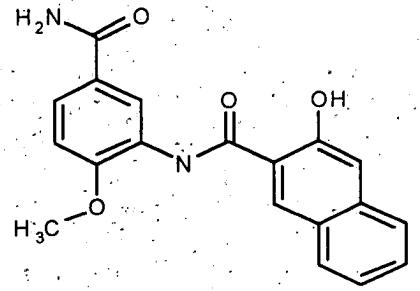
Cmpd	Molecular Structure	Cmpd	Molecular Structure
130		133	
131		134	
132		135	

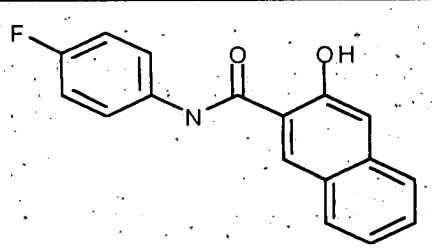
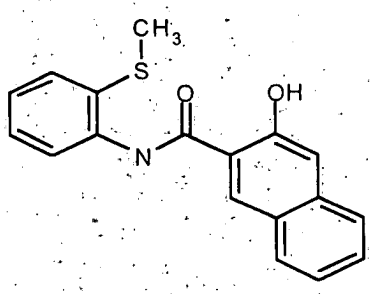
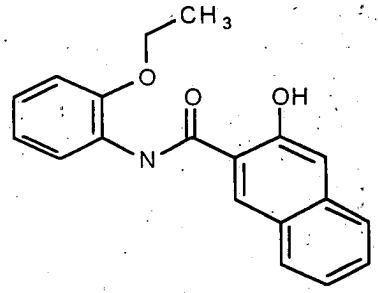
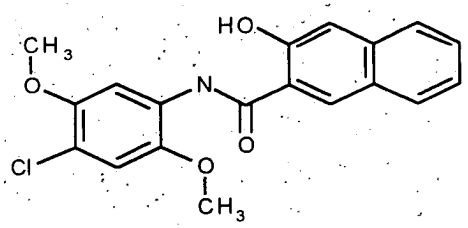
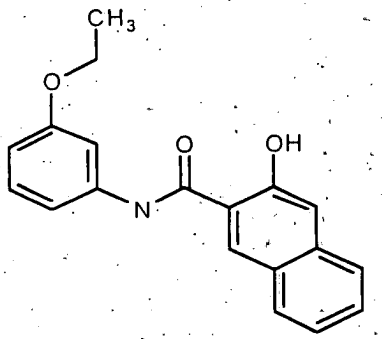
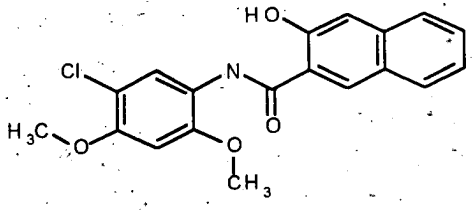
Cmpd	Molecular Structure	Cmpd	Molecular Structure
136		139	
137		140	
138		141	

Cmpd	Molecular Structure	Cmpd	Molecular Structure
142		145	
143		146	
144		147	

Cmpd	Molecular Structure	Cmpd	Molecular Structure
148		151	
149		152	
150		153	

Cmpd	Molecular Structure	Cmpd	Molecular Structure
154		157	
155			
156		159	

Cmpd	Molecular Structure	Cmpd	Molecular Structure
160		163	
161		164	
162		165	

Cmpd	Molecular Structure	Cmpd	Molecular Structure
166		169	
167		170	
168		171	

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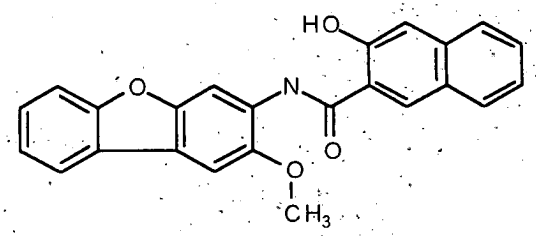
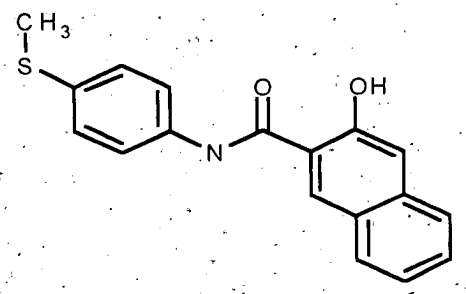
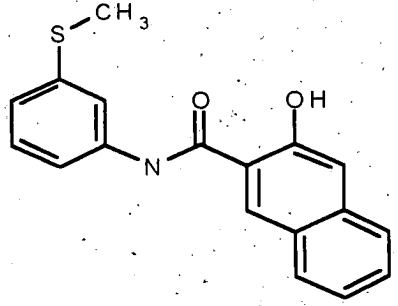
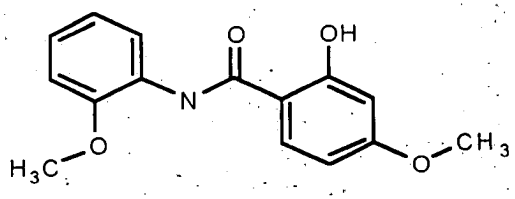
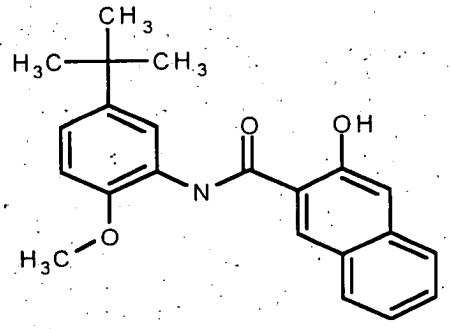
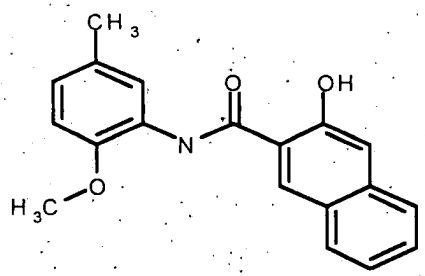
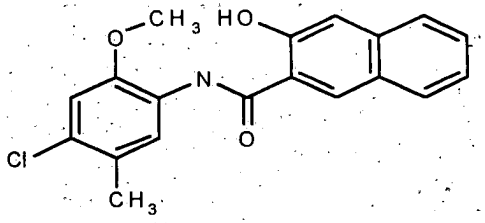
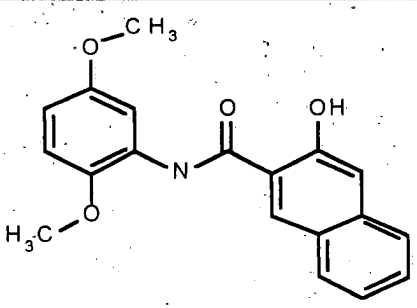
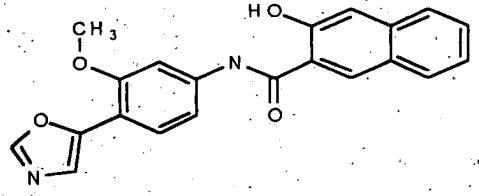
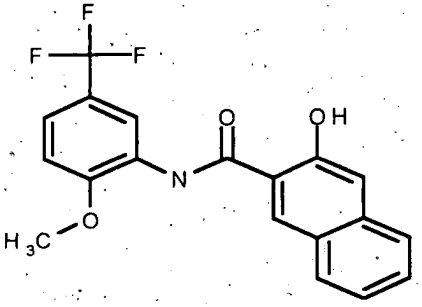
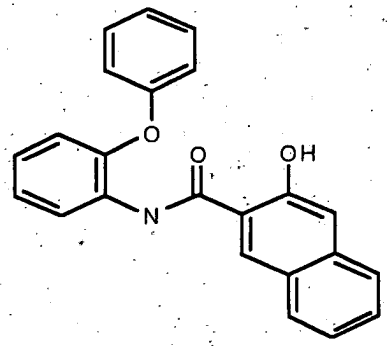
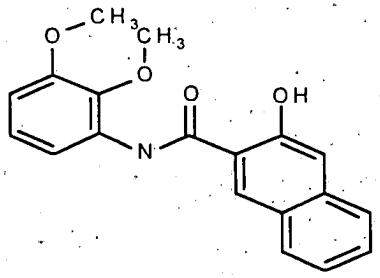
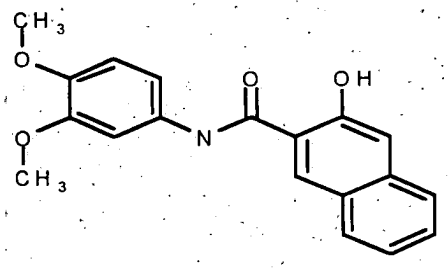
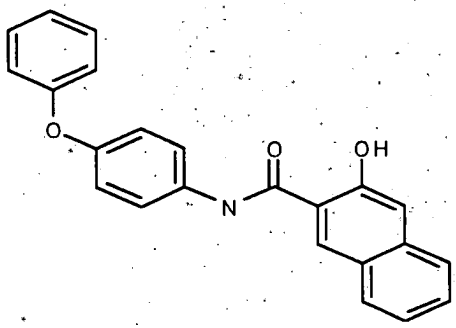
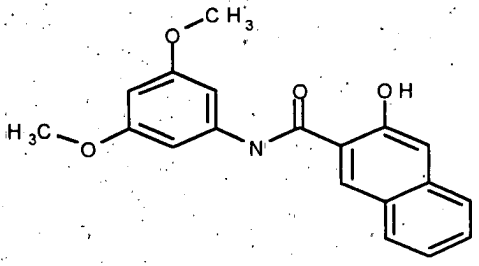
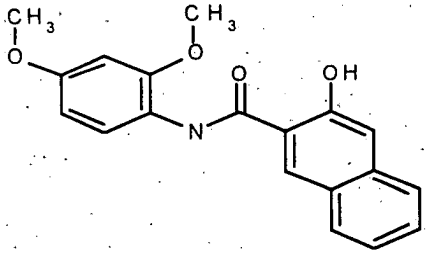
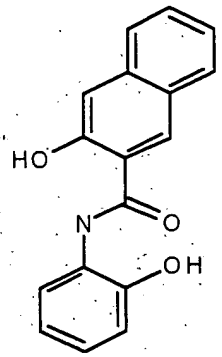
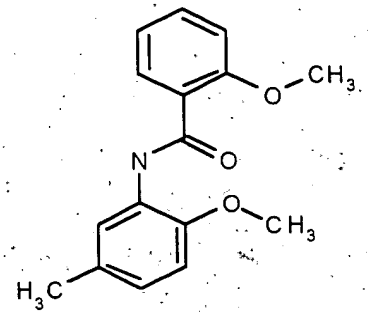
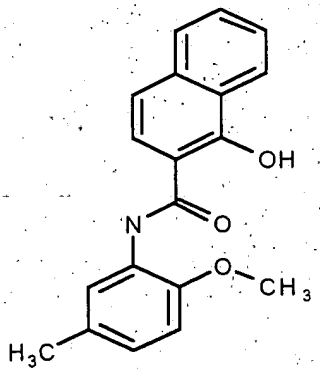
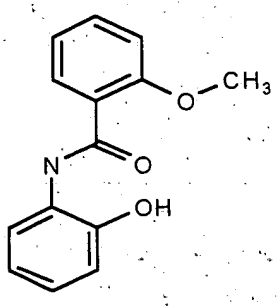
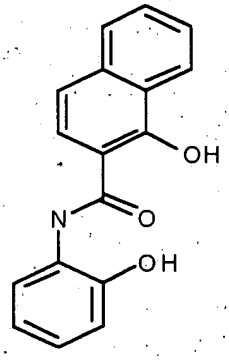
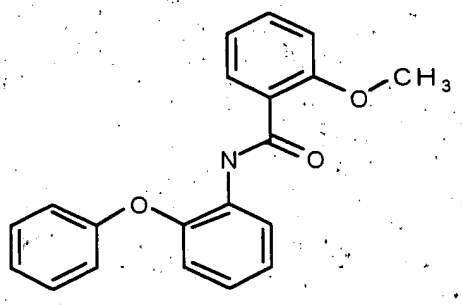
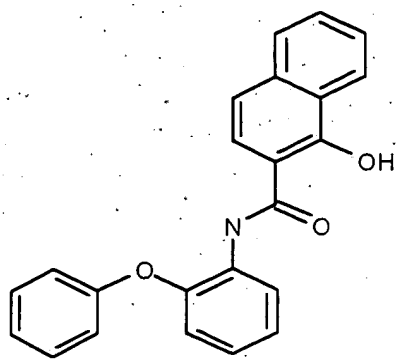
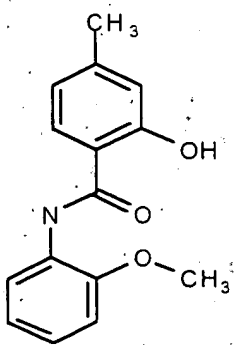
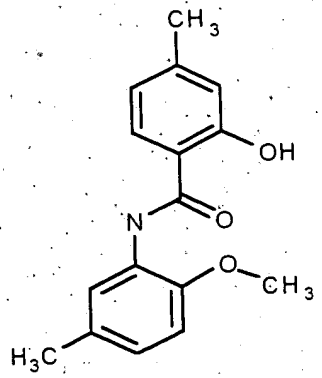
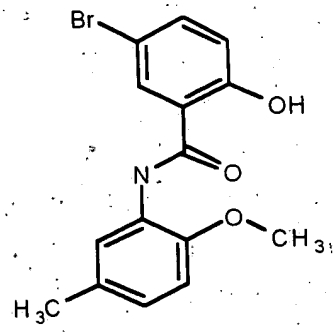
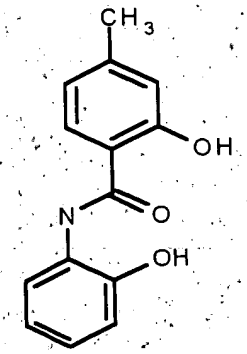
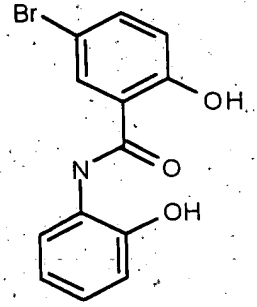
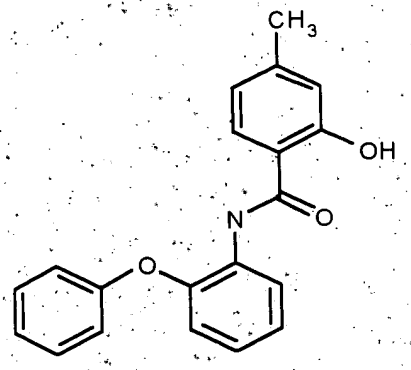
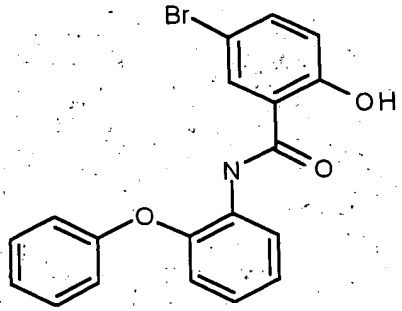
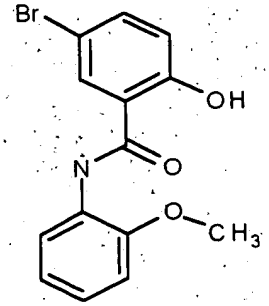
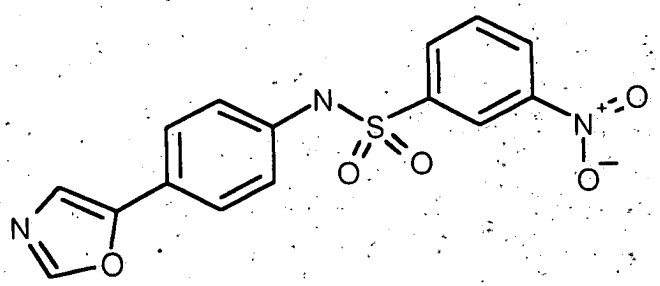
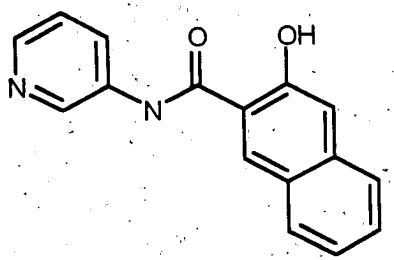
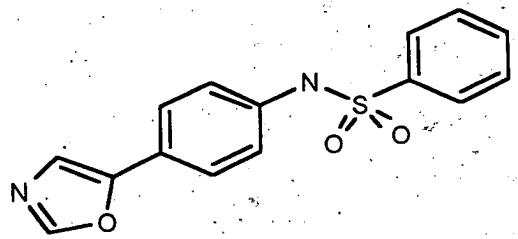
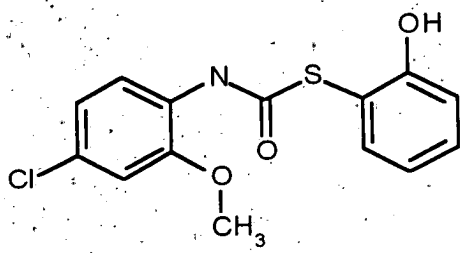
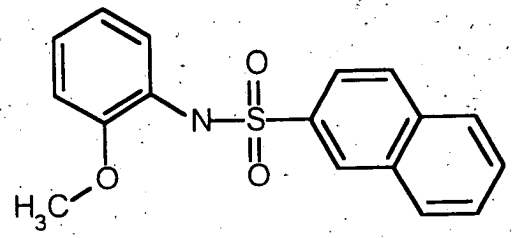
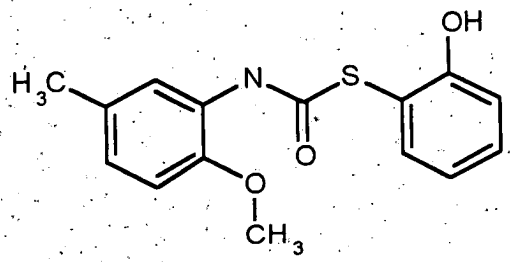
172		175	
173			
174		177	

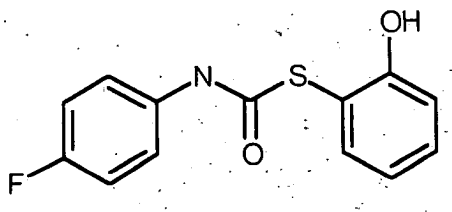
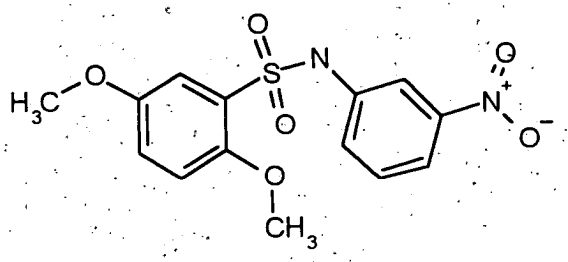
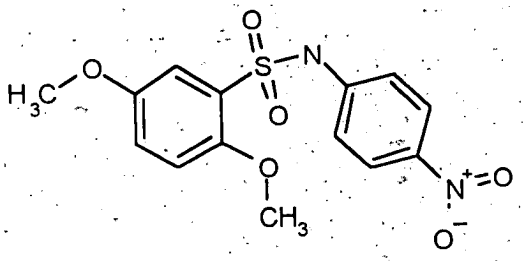
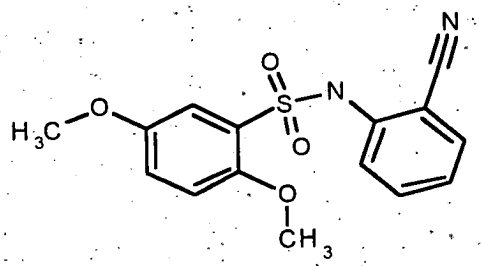
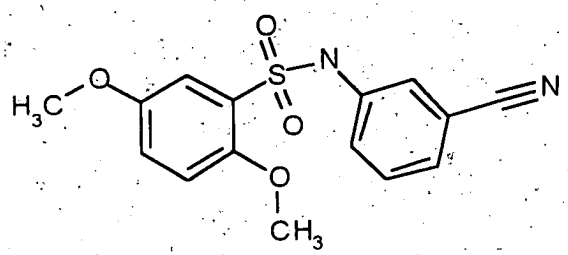
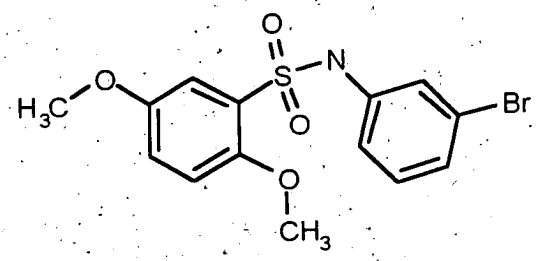
Cmpd	Molecular Structure	Cmpd	Molecular Structure
178		181	
179		182	
180		183	

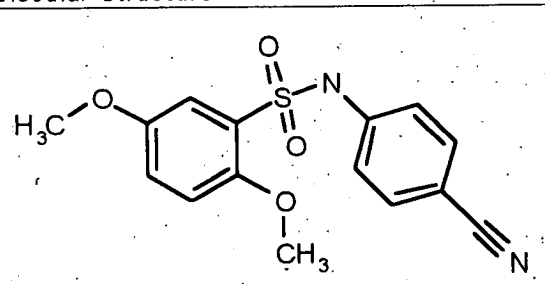
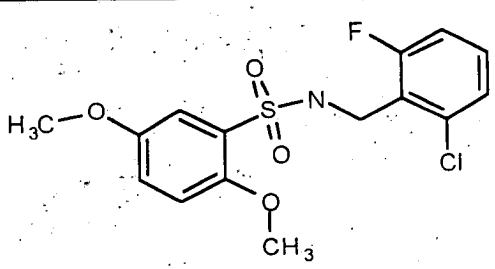
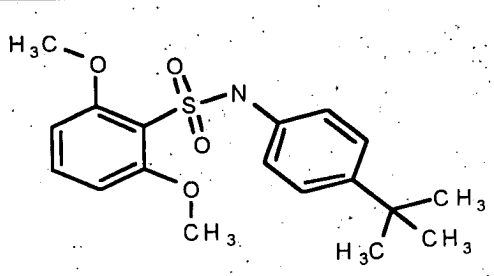
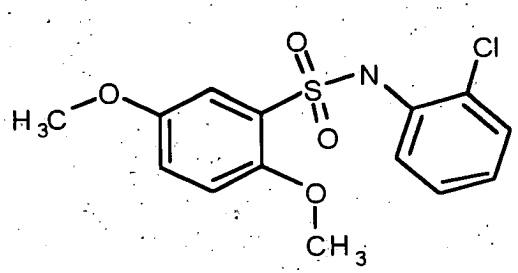
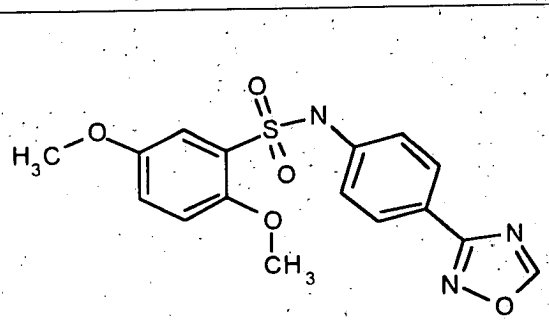
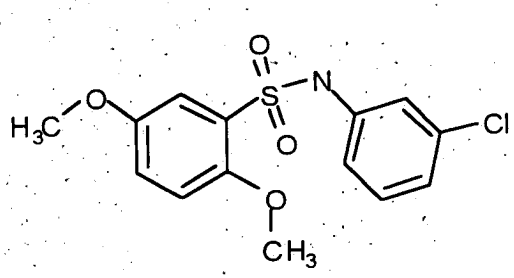
Cmpd	Molecular Structure	Cmpd	Molecular Structure
184		187	
185		188	
186			

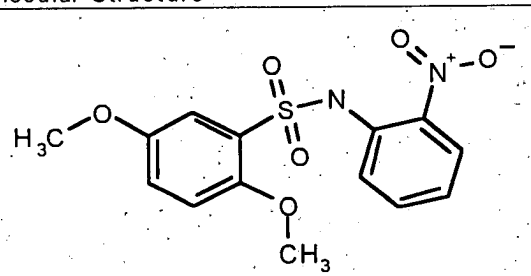
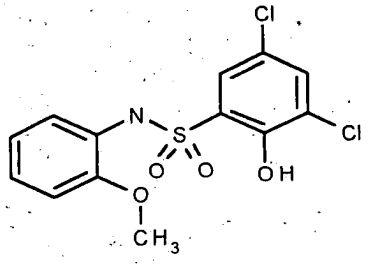
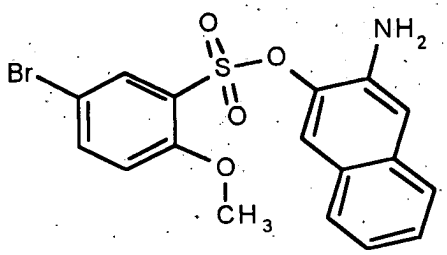
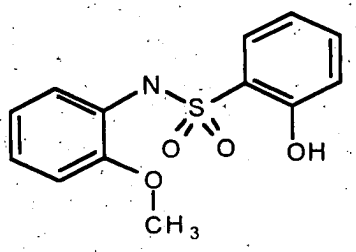
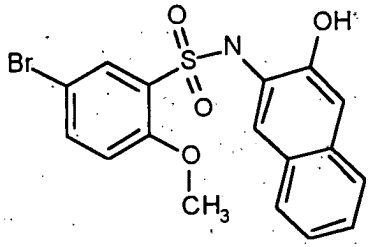
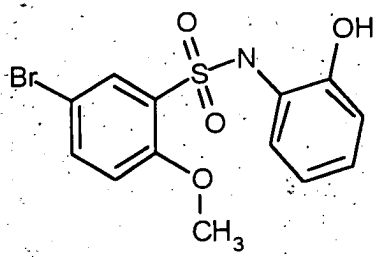
Cmpd	Molecular Structure	Cmpd	Molecular Structure
190		194	
191		195	
192		196	
193		197	

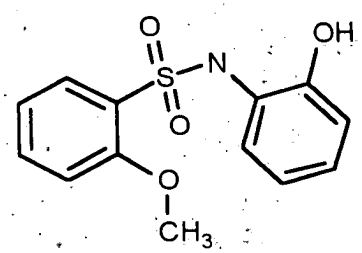
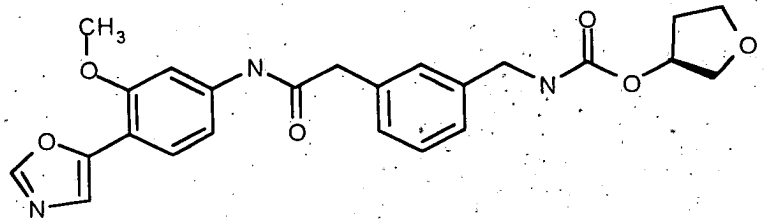
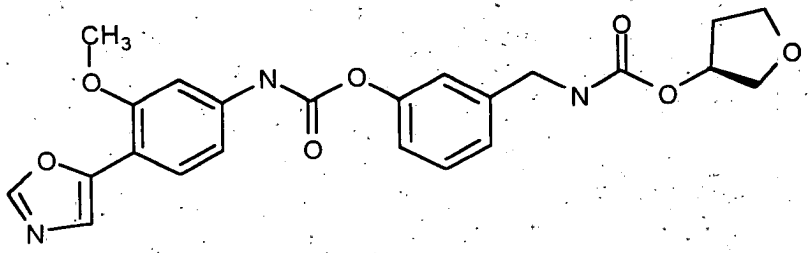
Cmpd	Molecular Structure	Cmpd	Molecular Structure
198		202	
199		203	
200		204	
201			

Cmpd	Molecular Structure	Cmpd	Molecular Structure
300		304	
301		305	
302		306	

Cmpd	Molecular Structure	Cmpd	Molecular Structure
303		307	
308		312	
309		313	

Cmpd	Molecular Structure	Cmpd	Molecular Structure
310		314	
311		315	
316		320	

Cmpd	Molecular Structure	Cmpd	Molecular Structure
317		321	
318		322	
319		323	

Cmpd	Molecular Structure
324	
325	
326	

The compounds of this invention may contain one or more asymmetric carbon atoms and thus may occur as racemates and racemic mixtures, single enantiomers, diastereomeric mixtures and individual diastereomers. All such isomeric forms of these compounds are expressly included in the present invention. Each stereogenic carbon may be of the R or S configuration.

Combinations of substituents and variables envisioned by this invention are only those that result in the formation of stable compounds. The term "stable", as used herein, refers to compounds which possess stability sufficient to allow manufacture and which maintains the integrity of the compound for a sufficient period of time to be useful for the purposes detailed herein (e.g., therapeutic or prophylactic administration to a mammal or for use in affinity chromatography applications). Typically, such compounds are stable at a temperature of 40°C or less, in the absence of moisture or other chemically reactive conditions, for at least a week.

As used herein, the compounds of this invention, are defined to include pharmaceutically acceptable derivatives or prodrugs thereof. A "pharmaceutically acceptable derivative or prodrug" means any pharmaceutically acceptable salt, ester, salt of an ester, or other derivative of a compound of this invention which, upon administration to a recipient, is capable of providing (directly or indirectly) a compound of this invention. Particularly favored derivatives and prodrugs are those that increase the bioavailability of the compounds of this invention when such compounds are administered to a mammal (e.g., by allowing an orally

administered compound to be more readily absorbed into the blood) or which enhance delivery of the parent compound to a biological compartment (e.g., the brain or lymphatic system) relative to the parent species. Preferred prodrugs include derivatives where a group which enhances aqueous solubility or active transport through the gut membrane is appended to the structure of the compounds of this invention.

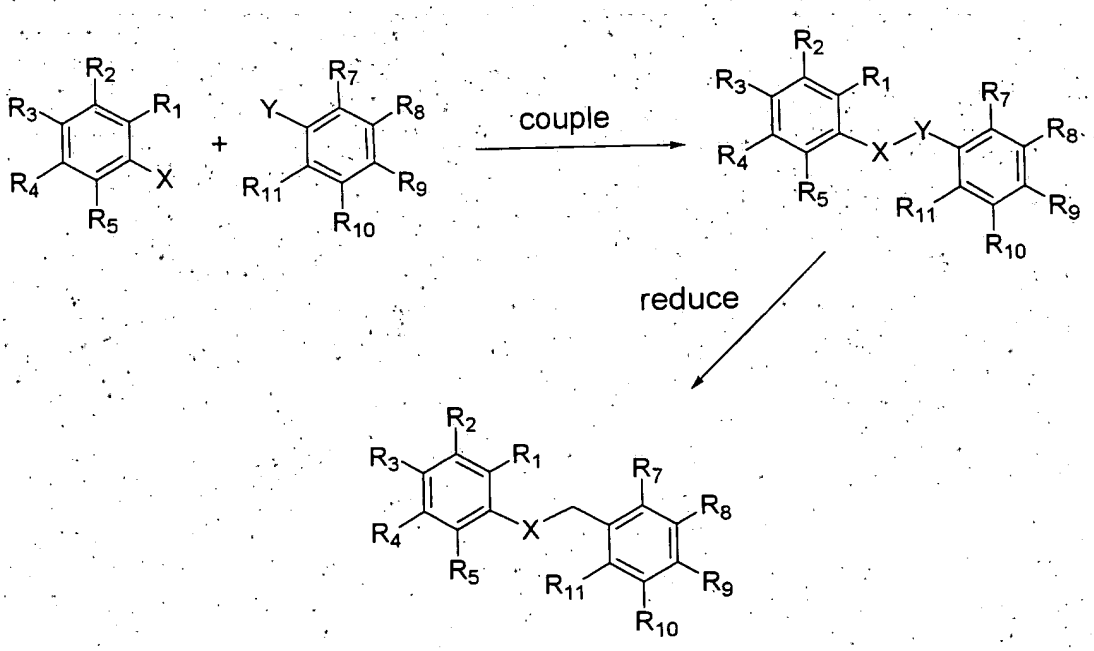
Pharmaceutically acceptable salts of the compounds of this invention include those derived from pharmaceutically acceptable inorganic and organic acids and bases. Examples of suitable acid salts include acetate, adipate, alginate, aspartate, benzoate, benzene sulfonate, bisulfate, butyrate, citrate, camphorate, camphor sulfonate, cyclopentanepropionate, digluconate, dodecylsulfate, ethanesulfonate, fumarate, glucoheptanoate, glycerophosphate, hemisulfate, heptanoate, hexanoate, hydrochloride, hydrobromide, hydroiodide, 2-hydroxyethanesulfonate, lactate, maleate, methanesulfonate, 2-naphthalenesulfonate, nicotinate, oxalate, pamoate, pectinate, persulfate, 3-phenyl-propionate, picrate, pivalate, propionate, succinate, tartrate, thiocyanate, tosylate and undecanoate. Base salts include ammonium salts, alkali metal salts, such as sodium and potassium salts, alkaline earth metal salts, such as calcium and magnesium salts, salts with organic bases, such as dicyclohexylamine salts, N-methyl-D-glucamine, and salts with amino acids such as arginine, lysine, and so forth.

Also, the basic nitrogen-containing groups can be quaternized with such agents as lower alkyl halides, such as methyl, ethyl, propyl, and butyl chloride,

bromides and iodides; dialkyl sulfates, such as dimethyl, diethyl, dibutyl and diamyl sulfates, long chain halides such as decyl, lauryl, myristyl and stearyl chlorides, bromides and iodides, aralkyl halides, such as benzyl and phenethyl bromides and others. Water or oil-soluble or dispersible products are thereby obtained.

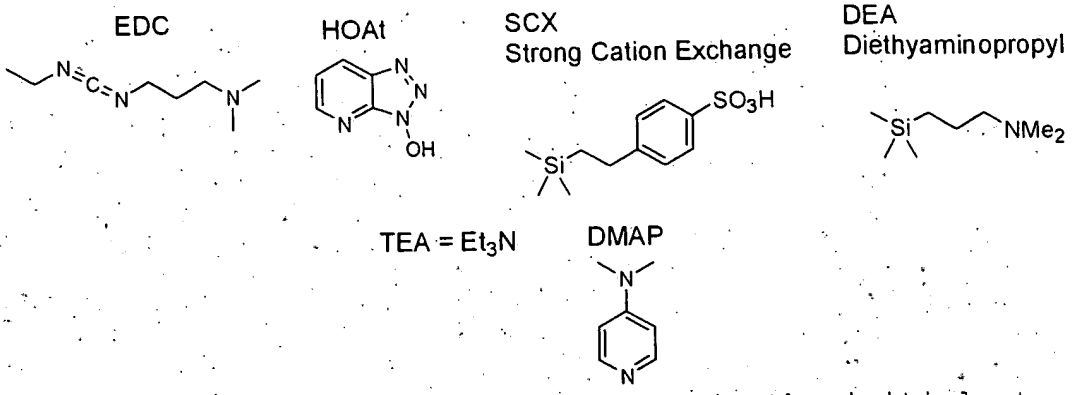
The compounds of this invention may be synthesized using conventional techniques. Advantageously, these compounds are conveniently synthesized from readily available starting materials.

In general, compounds of this invention are conveniently obtained via methods illustrated in Scheme 1 below:



The coupling step indicated in Scheme 1 was used to produce the benzamide, arylacetamide, sulfonamide, carbamate and thiocarbamate compounds of this invention.

Materials used for coupling and reduction are indicated below:



For benzamide synthesis, A in the initial step was $-N(H)R_6$ and B was $-C(O)OH$ or $-C(O)Cl$. The coupling was performed in the presence of EDC, HOAt and CH_3CN.

For arylacetamide synthesis, A in the initial step was $-N(H)R_6$ and B was $-Y-C(O)OH$ or $-Y-C(O)Cl$. The coupling was performed in the presence of EDC, CH_2Cl_2 and DMAP.

For sulfonamide synthesis, A in the initial step was $N(H)R_6$ and B was $S(O)_2Cl$. The coupling was performed in the presence of TEA and CH_2Cl_2.

For carbamate synthesis, A in the initial step was $N(H)R_6$ and B was $OC(O)Cl$. The coupling was performed in the presence of TEA and CH_2Cl_2.

For thiocarbamate synthesis, A in the initial step was NC(O) and B was SH. The coupling was performed in the presence of DMAP and CH_2Cl_2.

The reduction step indicated in scheme 1 was used to produce the benzyl amines of this invention. In the coupled molecule A'-B' was $N(R_6)-C(O)$ and reduction was carried out in the presence of $BH_3 \cdot THF/THF$.

The above reactions were carried out at room temperature for 5 hours with constant shaking.

Once synthesized, compounds were purified by solid phase extraction (SPE) on a bed of Varian DEA and

Varian SCX sorbents in a 2:1 ratio (w/w): 180 mg was packed into 1 mL cartridges.

The procedure is as follows:

Event	Volume	Flow rate
condition sorbent	1.5 ml	3 mL/min
load and collect	0.9 ml	3 mL/min
elute	1.5 ml	1 mL/min

The collected solution contained product at >95% purity (HPLC: 210 nm) with traces of O-acylated impurity. Yields were typically 8-12 mg.

As can be appreciated by the skilled artisan, the above synthetic schemes are not intended to comprise a comprehensive list of all means by which the compounds described and claimed in this application may be synthesized. Further methods will be evident to those of ordinary skill in the art. Additionally, the various synthetic steps described above may be performed in an alternate sequence or order to give the desired compounds.

The compounds of this invention may be modified by appending appropriate functionalities to enhance selective biological properties. Such modifications are known in the art and include those which increase biological penetration into a given biological compartment (e.g., blood, lymphatic system, central nervous system), increase oral availability, increase solubility to allow administration by injection, alter metabolism and alter rate of excretion.

The novel compounds of the present invention are excellent ligands for IMPDH. Accordingly, these compounds are capable of targeting and inhibiting IMPDH

enzyme. Inhibition can be measured by various methods, including, for example, IMP dehydrogenase HPLC assays (measuring enzymatic production of XMP and NADH from IMP and NAD) and IMP dehydrogenase spectrophotometric assays (measuring enzymatic production of NADH from NAD). [See C. Montero et al., Clinica Chimica Acta, 238, pp. 169-178 (1995)].

Compositions of this invention comprise a compound of this invention or a salt thereof; an additional agent selected from an immunosuppressant, an anti-cancer agent, an anti-viral agent, anti-inflammatory agent, antifungal agent, antibiotic, or an anti-vascular hyperproliferation compound; and any pharmaceutically acceptable carrier, adjuvant or vehicle. Alternate compositions of this invention comprise a compound of this invention or a salt thereof; and a pharmaceutically acceptable carrier, adjuvant or vehicle. Such composition may optionally comprise an additional agent selected from an immunosuppressant, an anti-cancer agent, an anti-viral agent, anti-inflammatory agent, antifungal agent, antibiotic, or an anti-vascular hyperproliferation compound. Preferably, the compositions of this invention are pharmaceutical compositions.

The term "pharmaceutically acceptable carrier or adjuvant" refers to a carrier or adjuvant that may be administered to a patient, together with a compound of this invention, and which does not destroy the pharmacological activity thereof and is nontoxic when administered in doses sufficient to deliver a therapeutic amount of the compound.

Pharmaceutically acceptable carriers, adjuvants and vehicles that may be used in the pharmaceutical

compositions of this invention include, but are not limited to, ion exchangers, alumina, aluminum stearate, lecithin, self-emulsifying drug delivery systems (SEDDS) such as dα-tocopherol polyethyleneglycol 1000 succinate, surfactants used in pharmaceutical dosage forms such as Tweens or other similar polymeric delivery matrices, serum proteins, such as human serum albumin, buffer substances such as phosphates, glycine, sorbic acid, potassium sorbate, partial glyceride mixtures of saturated vegetable fatty acids, water, salts or electrolytes, such as protamine sulfate, disodium hydrogen phosphate, potassium hydrogen phosphate, sodium chloride, zinc salts, colloidal silica, magnesium trisilicate, polyvinyl pyrrolidone, cellulose-based substances, polyethylene glycol, sodium carboxymethylcellulose, polyacrylates, waxes, polyethylene-polyoxypropylene-block polymers, polyethylene glycol and wool fat. Cyclodextrins such as α-, ß-, and γ-cyclodextrin, or chemically modified derivatives such as hydroxyalkylcyclodextrins, including 2- and 3-hydroxypropyl-ß-cyclodextrins, or other solubilized derivatives may also be advantageously used to enhance delivery of compounds of this invention.

The pharmaceutical compositions of this invention may be administered orally, parenterally, by inhalation spray, topically, rectally, nasally, buccally, vaginally or via an implanted reservoir. We prefer oral administration or administration by injection. The pharmaceutical compositions of this invention may contain any conventional non-toxic pharmaceutically-acceptable carriers, adjuvants or vehicles. In some cases, the pH of the formulation may be adjusted with pharmaceutically

acceptable acids, bases or buffers to enhance the stability of the formulated compound or its delivery form. The term parenteral as used herein includes subcutaneous, intracutaneous, intravenous, intramuscular, intra-articular, intraarterial, intrasynovial, intrasternal, intrathecal, intralesional and intracranial injection or infusion techniques.

The pharmaceutical compositions may be in the form of a sterile injectable preparation, for example, as a sterile injectable aqueous or oleaginous suspension. This suspension may be formulated according to techniques known in the art using suitable dispersing or wetting agents (such as, for example, Tween 80) and suspending agents. The sterile injectable preparation may also be a sterile injectable solution or suspension in a non-toxic parenterally-acceptable diluent or solvent, for example, as a solution in 1,3-butanediol. Among the acceptable vehicles and solvents that may be employed are mannitol, water, Ringer's solution and isotonic sodium chloride solution. In addition, sterile, fixed oils are conventionally employed as a solvent or suspending medium. For this purpose, any bland fixed oil may be employed including synthetic mono- or diglycerides. Fatty acids, such as oleic acid and its glyceride derivatives are useful in the preparation of injectables, as are natural pharmaceutically-acceptable oils, such as olive oil or castor oil, especially in their polyoxyethylated versions. These oil solutions or suspensions may also contain a long-chain alcohol diluent or dispersant such as those described in Pharmacopeia Helvetica, Ph. Helv., or a similar alcohol, or carboxymethyl cellulose or similar dispersing agents which are commonly used in the

formulation of pharmaceutically acceptable dosage forms such as emulsions and or suspensions Other commonly used surfactants such as Tweens or Spans and/or other similar emulsifying agents or bioavailability enhancers which are commonly used in the manufacture of pharmaceutically acceptable solid, liquid, or other dosage forms may also be used for the purposes of formulation.

The pharmaceutical compositions of this invention may be orally administered in any orally acceptable dosage form including, but not limited to, capsules, tablets, emulsions and aqueous suspensions, dispersions and solutions. In the case of tablets for oral use, carriers which are commonly used include lactose and corn starch. Lubricating agents, such as magnesium stearate, are also typically added. For oral administration in a capsule form, useful diluents include lactose and dried corn starch. When aqueous suspensions and/or emulsions are administered orally, the active ingredient may be suspended or dissolved in an oily phase is combined with emulsifying and/or suspending agents. If desired, certain sweetening and/or flavoring and/or coloring agents may be added.

The pharmaceutical compositions of this invention may also be administered in the form of suppositories for rectal administration. These compositions can be prepared by mixing a compound of this invention with a suitable non-irritating excipient which is solid at room temperature but liquid at the rectal temperature and therefore will melt in the rectum to release the active components. Such materials include, but are not limited to, cocoa butter, beeswax and polyethylene glycols.

Topical administration of the pharmaceutical compositions of this invention is especially useful when the desired treatment involves areas or organs readily accessible by topical application. For application topically to the skin, the pharmaceutical composition should be formulated with a suitable ointment containing the active components suspended or dissolved in a carrier. Carriers for topical administration of the compounds of this invention include, but are not limited to, mineral oil, liquid petroleum, white petroleum, propylene glycol, polyoxyethylene polyoxypropylene compound, emulsifying wax and water. Alternatively, the pharmaceutical composition can be formulated with a suitable lotion or cream containing the active compound suspended or dissolved in a carrier with suitable emulsifying agents. Suitable carriers include, but are not limited to, mineral oil, sorbitan monostearate, polysorbate 60, cetyl esters wax, cetearyl alcohol, 2-octyldodecanol, benzyl alcohol and water. The pharmaceutical compositions of this invention may also be topically applied to the lower intestinal tract by rectal suppository formulation or in a suitable enema formulation. Topically-transdermal patches are also included in this invention.

The pharmaceutical compositions of this invention may be administered by nasal aerosol or inhalation. Such compositions are prepared according to techniques well-known in the art of pharmaceutical formulation and may be prepared as solutions in saline, employing benzyl alcohol or other suitable preservatives, absorption promoters to enhance bioavailability,

fluorocarbons, and/or other solubilizing or dispersing agents known in the art.

Dosage levels of between about 0.01 and about 100 mg/kg body weight per day, preferably between about 0.5 and about 75 mg/kg body weight per day of the IMPDH inhibitory compounds described herein are useful in a monotherapy and/or in combination therapy for the prevention and treatment of IMPDH mediated disease. Typically, the pharmaceutical compositions of this invention will be administered from about 1 to about 5 times per day or alternatively, as a continuous infusion. Such administration can be used as a chronic or acute therapy. The amount of active ingredient that may be combined with the carrier materials to produce a single dosage form will vary depending upon the host treated and the particular mode of administration. A typical preparation will contain from about 5% to about 95% active compound (w/w). Preferably, such preparations contain from about 20% to about 80% active compound.

When the compositions of this invention comprise a combination of an IMPDH inhibitor of this invention and one or more additional therapeutic or prophylactic agents, both the IMPDH inhibitor and the additional agent should be present at dosage levels of between about 10 to 100%, and more preferably between about 10 to 80% of the dosage normally administered in a monotherapy regimen. The additional agents may be administered separately, as part of a multiple dose regimen, from the compounds of this invention. Alternatively, those agents may be part of a single dosage form, mixed together with the compounds of this invention in a single composition.

According to one embodiment, the pharmaceutical compositions of this invention comprise an additional immunosuppression agent. Examples of additional immunosuppression agents include, but are not limited to, cyclosporin A, FK506, rapamycin, leflunomide, deoxyspergualin, prednisone, azathioprine, mycophenolate mofetil, OKT3, ATAG, interferon and mizoribine.

According to an alternate embodiment, the pharmaceutical compositions of this invention may additionally comprise an anti-cancer agent. Examples of anti-cancer agents include, but are not limited to, cis-platin, actinomycin D, doxorubicin, vincristine, vinblastine, etoposide, amsacrine, mitoxantrone, tenipaside, taxol, colchicine, cyclosporin A, phenothiazines, interferon and thioxantheres.

According to another alternate embodiment, the pharmaceutical compositions of this invention may additionally comprise an anti-viral agent. Examples of anti-viral agents include, but are not limited to, Cytovene, Ganciclovir, trisodium phosphonoformate, Ribavirin, d4T, ddI, AZT, and acyclovir.

According to yet another alternate embodiment, the pharmaceutical compositions of this invention may additionally comprise an anti-vascular hyperproliferative agent. Examples of anti-vascular hyperproliferative agents include, but are not limited to, HMG Co-A reductase inhibitors such as lovastatin, thromboxane A2 synthetase inhibitors, eicosapentanoic acid, ciprostene, trapidil, ACE inhibitors, low molecular weight heparin, mycophenolic acid, rapamycin and 5-(3'-pyridinylmethyl)benzofuran-2-carboxylate.

Upon improvement of a patient's condition, a maintenance dose of a compound, composition or combination of this invention may be administered, if necessary. Subsequently, the dosage or frequency of administration, or both, may be reduced, as a function of the symptoms, to a level at which the improved condition is retained when the symptoms have been alleviated to the desired level, treatment should cease. Patients may, however, require intermittent treatment on a long-term basis upon any recurrence of disease symptoms.

As the skilled artisan will appreciate, lower or higher doses than those recited above may be required. Specific dosage and treatment regimens for any particular patient will depend upon a variety of factors, including the activity of the specific compound employed, the age, body weight, general health status, sex, diet, time of administration, rate of excretion, drug combination, the severity and course of the infection, the patient's disposition to the infection and the judgment of the treating physician.

In an alternate embodiment, this invention provides methods of treating or preventing IMPDH mediated disease in a mammal comprising the step of administrating to said mammal any of the pharmaceutical compositions and combinations described above. If the pharmaceutical composition only comprises the IMPDH inhibitor of this invention as the active component, such methods may additionally comprise the step of administering to said mammal an agent selected from an anti-inflammatory agent, immunosuppressant, an anti-cancer agent, an anti-viral agent, or an anti-vascular hyperproliferation compound. Such additional agent may be administered to the mammal

prior to, concurrently with, or following the administration of the IMPDH inhibitor composition.

In a preferred embodiment, these methods are useful in suppressing an immune response in a mammal. Such methods are useful in treating or preventing diseases, including, transplant rejection (e.g., kidney, liver, heart, lung, pancreas (islet cells), bone marrow, cornea, small bowel and skin allografts and heart valve xenografts), graft versus host disease, and autoimmune diseases, such as rheumatoid arthritis, multiple sclerosis, juvenile diabetes, asthma, inflammatory bowel disease (Crohn's disease, ulcerative colitus), lupus, diabetes, mellitus myasthenia gravis, psoriasis, dermatitis, eczema, seborrhea, pulmonary inflammation, eye uveitis, Grave's disease, Hashimoto's thyroiditis, Behcet's or Sjorgen's syndrome (dry eyes/mouth), pernicious or immunohaemolytic anaemia, idiopathic adrenal insufficiency, polyglandular autoimmune syndrome, glomerulonephritis, scleroderma, lichen planus, viteligo (depigmentation of the skin), autoimmune thyroiditis, and alveolitis.

These methods comprise the step of administering to the mammal a composition comprising a compound of this invention and a pharmaceutically acceptable adjuvant. In a preferred embodiment, this particular method comprises the additional step of administering to said mammal a composition comprising an additional immunosuppressant and a pharmaceutically acceptable adjuvant.

Alternatively, this method comprises the step of administering to said mammal a composition comprising a compound of this invention; an additional

immunosuppressive agent and a pharmaceutically acceptable adjuvant.

In an alternate preferred embodiment, these methods are useful for inhibiting viral replication in a mammal. Such methods are useful in treating or preventing DNA and RNA viral diseases caused by infection for example, by orthomyxoviruses (influenza viruses types A and B), paramyxoviruses (respiratory syncytial virus (RSV), subacute sclerosing panencephalitis (SSPE) virus) measles and parainfluenza type 3), herpesviruses (HSV-1, HSV-2, HHV-6, HHV-7, HHV-8, Epstein Barr Virus (EBV), cytomegalovirus (HCMV) and varicella zoster virus (VZV)), retroviruses (HIV-1, HIV-2, HTLV-1, HTLV-2), flavi- and pestiviruses (yellow fever virus (YFV), hepatitis C virus (HCV), dengue fever virus, bovine viral diarrhea virus (BVDV), hepatotrophic viruses (hepatitis A virus (HAV), hepatitis B virus (HBV), HCV, hepatitis D virus (HDV), hepatitis E virus (HEV), hepatitis G virus (HGV), Crimean-Congo hemorrhagic fever virus (CCHF), bunyaviruses (Punta Toro virus, Rift Valley fever virus (RVFV), and sandfly fever Sicilian virus), Hantaan virus, Caraparu virus), human papilloma viruses, encephalitis viruses (La Crosse virus), arena viruses (Junin and Tacaribe virus), reovirus, vesicular stomatitis virus, rhinoviruses, enteroviruses (polio virus, coxsackie viruses, encephalomyocarditis virus (EMC)), Lassa fever virus, and togaviruses (Sindbis and Semlike forest viruses) and poxviruses (vaccinia virus), adenoviruses, rubiola, and rubella.

These methods comprise the step of administering to the mammal a composition comprising a compound of this invention, and a pharmaceutically

acceptable adjuvant. In a preferred embodiment, this particular method comprises the additional step of administering to said mammal a composition comprising an additional anti-viral agent and a pharmaceutically acceptable adjuvant.

Alternatively, this method comprises the step of administering to said mammal a composition comprising a compound of this invention; an additional anti-viral agent and a pharmaceutically acceptable adjuvant.

In another alternate preferred embodiment, these methods are useful for inhibiting vascular cellular hyperproliferation in a mammal. Such methods are useful in treating or preventing diseases, including, restenosis, stenosis, artherosclerosis and other hyperproliferative vascular disease.

These methods comprise the step of administering to the mammal a composition comprising a compound of this invention, and a pharmaceutically acceptable adjuvant. In a preferred embodiment, this particular method comprises the additional step of administering to said mammal a composition comprising an additional anti-vascular hyperproliferative agent and a pharmaceutically acceptable adjuvant.

Alternatively, this method comprises the step of administering to said mammal a composition comprising a compound of this invention; an additional anti-vascular hyperproliferative agent and a pharmaceutically acceptable adjuvant.

In another alternate preferred embodiment, these methods are useful for inhibiting tumors and cancer in a mammal. Such methods are useful in treating or

preventing diseases, including, tumors and malignancies, such as lymphoma, leukemia and other forms of cancer.

These methods comprise the step of administering to the mammal a composition comprising a compound of this invention, and a pharmaceutically acceptable adjuvant. In a preferred embodiment, this particular method comprises the additional step of administering to said mammal a composition comprising an additional anti-tumor or anti-cancer agent and a pharmaceutically acceptable adjuvant.

Alternatively, this method comprises the step of administering to said mammal a composition comprising a compound of this invention; an additional anti-tumor or anti-cancer agent and a pharmaceutically acceptable adjuvant.

In another alternate preferred embodiment, these methods are useful for inhibiting inflammation and inflammatory diseases in a mammal. Such methods are useful in treating or preventing diseases, including, osteoarthritis, acute pancreatitis, chronic pancreatitis, asthma and adult respiratory distress syndrome.

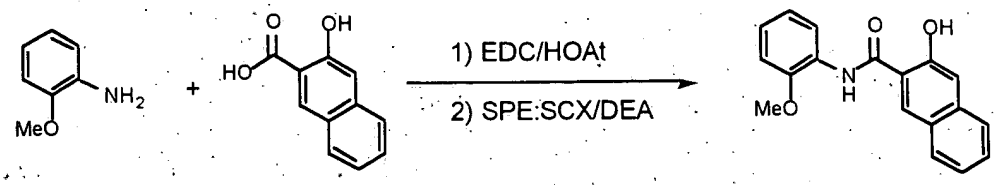
These methods comprise the step of administering to the mammal a composition comprising a compound of this invention, and a pharmaceutically acceptable adjuvant. In a preferred embodiment, this particular method comprises the additional step of administering to said mammal a composition comprising an anti-inflammatory agent and a pharmaceutically acceptable adjuvant.

In order that this invention be more fully understood, the following examples are set forth. These examples are for the purpose of illustration only and are

not to be construed as limiting the scope of the invention in any way.

EXAMPLE 1

Synthesis of Compound 100



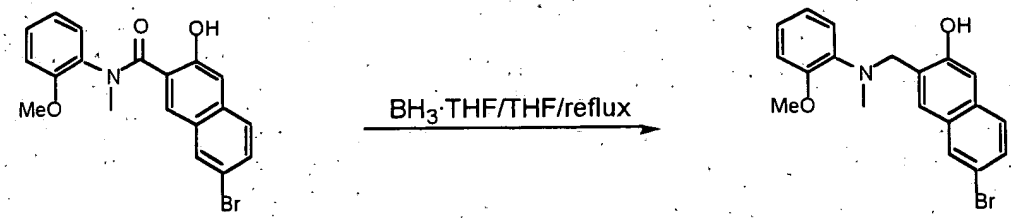
Solutions of acid (80 µL, 32 µmol) and aniline (100 µL, µmol) in THF were dispensed into a teflon 96-well plate. A solution containing 0.4*M* EDC.HCl and 0.4M HOAt in MeCN (100 µL, 40 µmol) was added and the reactions mixed in a vortex shaker for 5h. MeOH (500 µL) was added.

HPLC-MS data: retention time in 0.1% TFA: 8.81 min.

LRMS (EI): 294.1 (M + H, relative intensity 100%)

EXAMPLE 2

Synthesis of Compound 103:



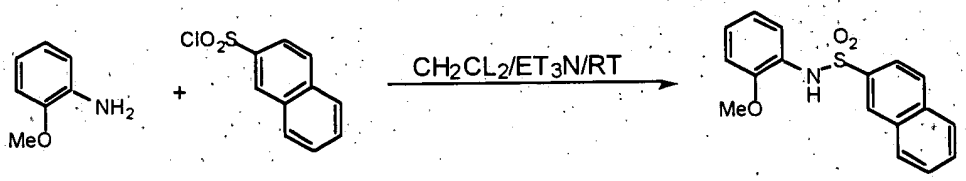
To a room temperature solution of the amide (65 mg, 0.168 mmole) in 5 ml of THF was added $BH_3 \cdot THF$ (0.45 ml, 0.539 mmole). The resulting mixture was heated to reflux overnight, then cooled to room temperature, and concentrated *in vacuo*. The resulting crude product was

diluted in 5 ml of saturated HCl in MeOH and heated to reflux for 3 hours. The resulting mixture was cooled to room temperature, diluted with ethyl acetate, washed successively with saturated $NaHCO_3$, water, brine, then dried over Na_2SO_4. The crude product was purified by silica-gel chromatography (9/1 hexanes/ether) to give 33 mg (53% yield) of the desired benzylamine.

^1H NMR ($CDCl_3$, 500 MHz): 10.51 (1H, broad s); 7.96 (1H, s); 7.67 (1H, d); 7.57 (1H, s); 7.55 (1H, dd); 7.34 (1H, s); 7.32 (1H, d); 7.26 (1H, dd); 7.09 (1H, dd); 7.04 (1H, d); 4.41 (2H, s); 4.06 (3H, s); 2.75 (3H, s).

EXAMPLE 3

Synthesis of Compound 302

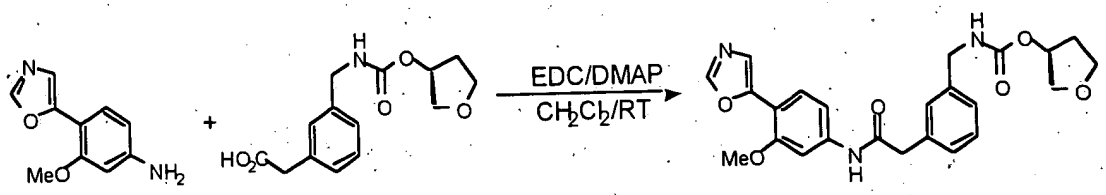


To a 0°C solution of the sulfonyl chloride (100 mg, 0.44 mmoles) in CH_2Cl_2 (5 mL) was added *o*-anisidine (45mL, 0.44 mmoles). The resulting mixture was allowed to warm to room temperature and stirred overnight. The crude reaction was diluted with ethyl acetate, washed with sat. $NaHCO_3$, 0.5 N HCl, brine, dried over Na_2SO_4, filtered, and concentrated *in vacuo*. The crude product was purified by MPLC to give the 88 mg (64%) of the desired sulfonamide.

^1H NMR ($CDCl_3$, 500 MHz): 8.31 (1H, s); 7.82 (3H, m); 7.70 (1H, d); 7.54 (3H, m); 7.06 (1H, s); 6.97 (1H, dd); 6.88 (1H, dd); 6.67 (1H, d); 3.56 (3H, s)

EXAMPLE 4

Synthesis of Compound 325

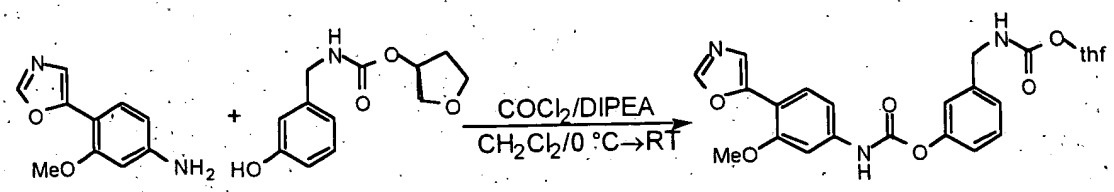


To a room temperature solution of the acid (76 mg, 0.272 mmole) in CH_2Cl_2 (4 ml) was added the aniline (57 mg, 0.30 mmole), EDC (104 mg, 0.544 mmole) and DMAP (catalytic amount). The resulting mixture was stirred at room temperature for 16 hours, then diluted with ethyl acetate and water. The phases were separated and the organic phase was washed with 1.0 N HCl, sat. $NaHCO_3$, brine, dried over Na_2SO_4, filtered and concentrated *in vacuo*. Crude product was purified via flash chromatography to give 56 mg (46%) of the desired amide as a white solid.

^1H NMR (DMSO-d_6, 500 MHz): 10.50 (1H, s); 8.40 (1H, s); 7.85 (1H, broad t); 7.65 (1H, d); 7.45 (1H, s); 7.50-7.35 (3H, m); 7.30-7.10 (4H, m); 5.15 (1H, broad m); 4.20 (2H, d); 3.90 (3H, s); 3.80-3.60 (4H, m); 2.10 (1H, m); 1.85 (1H, m).

EXAMPLE 5

Synthesis of Compound 326



To a stirred, 0°C solution of the phenol (86 mg, 0.362 mmole) in CH_2Cl_2 (1.5 mL) was added DIPEA (59 mL, 0.434 mmole) and phosgene (742 mL, 0.74 mmole, 1.0 M in PhMe). The resulting solution was warmed to room temperature, stirred for 2.5 hours, then concentrated *in vacuo*. The resulting chloroformate was diluted in CH_2Cl_2 (2 mL), cooled to 0 °C, then treated with a CH_2Cl_2 solution of the aniline (83 mg, 0.434 mmole) and DIPEA (74 mL, 0.543 mmole). The resulting mixture was stirred at room temperature overnight, then diluted in ethyl acetate and water. The phases were separated, the organic phase washed with sat. $NaHCO_3$, brine, dried over Na_2SO_4, filtered, and concentrated *in vacuo*. The crude product was purified by flash chromatography to give 40 mg (24%) of the desired carbamate as a slightly yellow foam.

^1H NMR (DMSO-d_6, 500 MHz): 10.40 (1H, s); 8.38 (1H, s); 7.80 (1H, broad t); 7.62 (1H, d); 7.58 (1H, d); 7.45 (1H, s); 7.30-7.10 (5H, m); 5.12 (1H, m); 4.18 (2H, d); 3.90 (3H, s); 3.80-3.60 (4H, m); 3.65 (2H, s); 2.10 (1H, m); 1.95 (1H, m).

EXAMPLE 6

IMPDH Activity Inhibition Assay

IMP dehydrogenase activity was assayed following an adaptation of the method first reported by Magasanik. [B. Magasanik et al., J. Biol. Chem., 226, p. 339 (1957), the disclosure of which is herein incorporated by reference]. Enzyme activity was measured spectrophotometrically, by monitoring the increase in absorbance at 340 nm due to the formation of NADH (ε340 is 6220 M^{-1} cm^{-1}). The reaction mixture contained 0.1 M Tris pH 8.0, 0.1 M KCl, 3 mM EDTA, 2 mM DTT, 0.1 M IMP and enzyme (IMPDH human type II) at a concentration of 15 to 50 nM. This solution is incubated at 37°C for 10 minutes. The reaction is started by adding NAD to a final concentration of 0.1M and the initial rate is measured by following the linear increase in absorbance at 340 nm for 10 minutes. For reading in a standard spectrophotometer (path length 1 cm) the final volume in the cuvette is 1.0 ml. The assay has also been adapted to a 96 well microtiter plate format; in this case the concentrations of all the reagents remain the same and the final volume is decreased to 200 µl.

For the analysis of inhibitors, the compound in question is dissolved in DMSO to a final concentration of 20 mM and added to the initial assay mixture for preincubation with the enzyme at a final volume of 2- 5% (v/v). The reaction is started by the addition of NAD, and the initial rates measured as above. K_i determinations are made by measuring the initial velocities in the presence of varying amounts of inhibitor and fitting the data using the tight-binding

equations of Henderson (Henderson, P. J. F. (1972) Biochem. J. 127, 321].

These results are shown in Table 2. Category "A" indicates a K_I of less than 10 μM, category "B" indicates a K_I of between 10 and 20 μM, category "C" indicates a K_I greater than 20 μM.

Table 2. IMPDH inhibitory activity.

Compound	Ki	Compound	Ki	Compound	Ki
100	A	143	A	188	B
101	B	144	B	190	C
102	A	145	B	191	C
103	B	146	B	192	C
104	B	147	A	193	B
105	B	148	B	194	C
106	B	149	B	195	B
107	B	150	B	196	B
108	B	151	A	197	C
109	A	152	B	198	C
110	B	153	A	199	C
111	A	154	B	200	B
112	B	155	B	201	B
113	A	156	B	202	C
114	A	157	B	203	C
115	A	159	B	204	C
116	C	160	B	300	B
117	C	161	A	301	B
118	B	162	B	302	B
119	C	163	B	303	C
120	B	164	A	304	C
121	B	165	B	305	A
122	B	166	B	306	B
123	A	167	B	307	B
124	A	168	B	308	B
125	B	169	A	309	B
126	A	170	A	310	B
127	A	171	B	311	B
128	B	172	A	312	B
129	B	173	B	313	B
130	B	174	B	314	B
131	B	175	A	315	B
132	B	177	B	316	B
133	B	178	A	317	B
134	B	179	B	318	B
135	B	180	B	319	B

Compound	Ki	Compound	Ki	Compound	Ki
136	B	181	A	320	B
137	B	182	A	321	B
138	A	183	A	322	B
139	A	184	B	323	B
140	A	185	A	324	B
141	A	186	B	325	A
142	B	187	B	326	A

Other compounds of this invention will also have IMPDH inhibitory activity.

EXAMPLE 7

Anti-Viral Assays

The anti-viral efficacy of compounds may be evaluated in various in vitro and in vivo assays. For example, compounds may be tested in in vitro viral replication assays. In vitro assays may employ whole cells or isolated cellular components. In vivo assays include animal models for viral diseases. Examples of such animal models include, but are not limited to, rodent models for HBV or HCV infection, the Woodchuck model for HBV infection, and chimpanzee model for HCV infection.

While we have hereinbefore presented a number of embodiments of this invention, it is apparent that my basic construction can be altered to provide other embodiments which utilize the methods of this invention. Therefore, it will be appreciated that the scope of this invention is to be defined by the claims appended hereto rather than the specific embodiments which have been presented hereinbefore by way of example.